Energy & Sustainability

Conventional, Renewable and Transitional

Presenter:

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SENS 714

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Prof. Muammer Koç

Dr. Khalid M. Al-Khori

❑ ***Education:***

✓ **BSc. degree of Science in Electrical Engineering** from University of Miami; Florida 1997

✓ **EMBA in Energy** from HEC Paris; Doha 2014

✓ **Ph.D. in Sustainable Energy** from HBKU; Doha 2020.

❑ ***Career:***

✓ Total experience of 27 years in Oil & Gas sector.

✓ Started career as Process Control Engineer in QP-Refinery

✓ Join Dolphin Energy in 2010 and currently **Engineering Director**.

❑ ***Award:***

✓ Recipient of the **Platinum Award for PhD** from HH Sheikh Tamim bin Hamad Al Thani – Amir of the State of Qatar during the **Education Excellence Award Day 2022**.

Energy

Contents

Energy: Role & Impacts

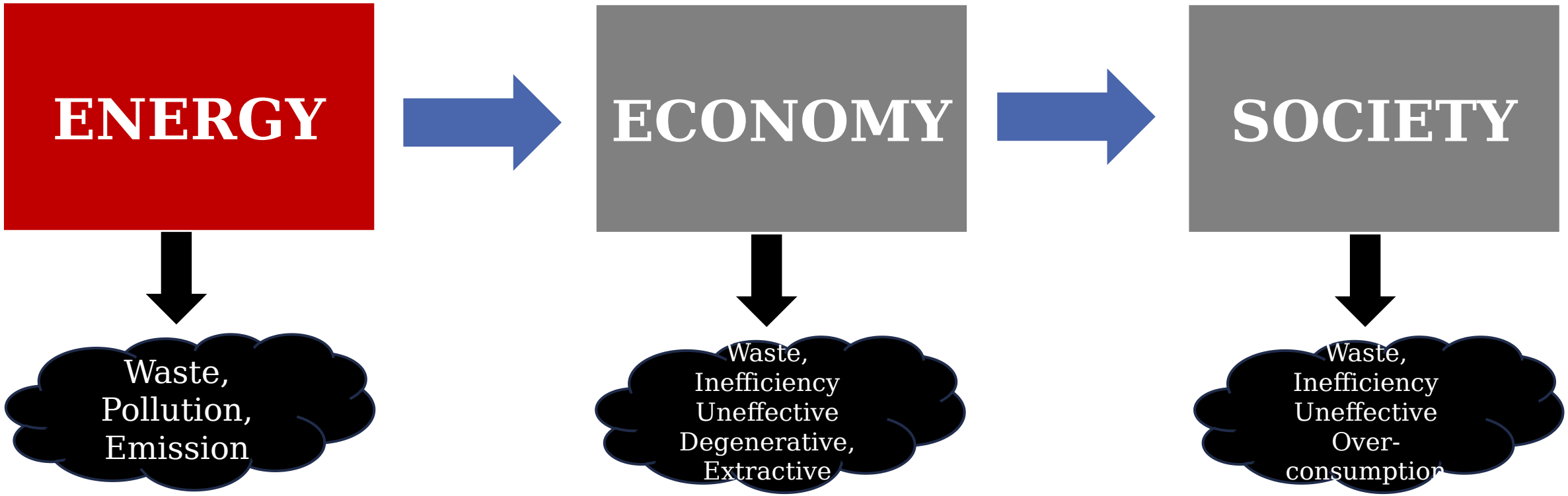
Energy -Roles and Impacts

Energy is a driver for economy and society

Energy- Roles and Impacts

Energy is a **driver** for economy and society.

If it is **not clean**, then it will have an **unsustainable impact**



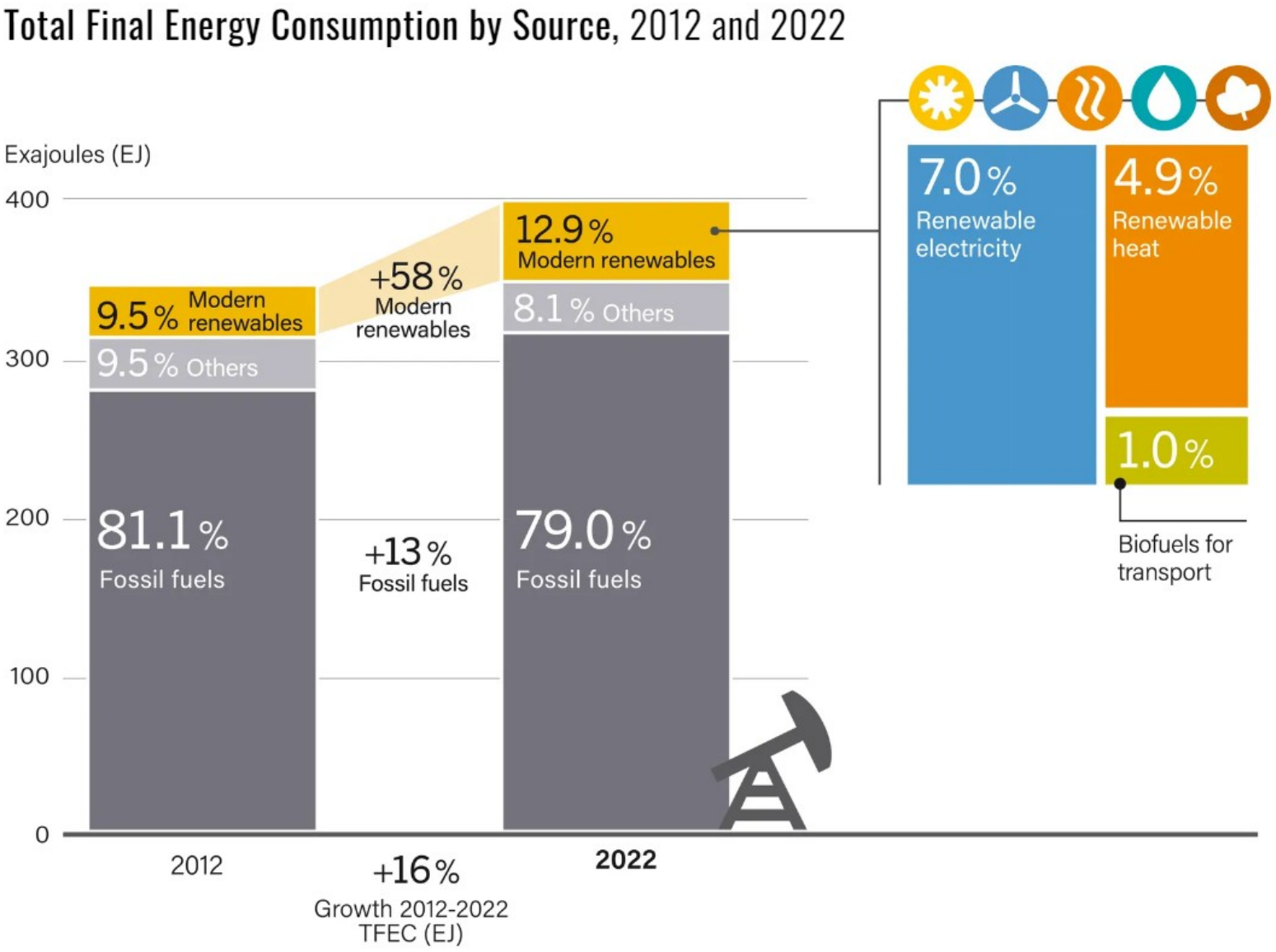
Energy- Roles and Impacts

Energy is a **driver** for economy and society.

If it is **clean**, then it will have an **sustainable impact**

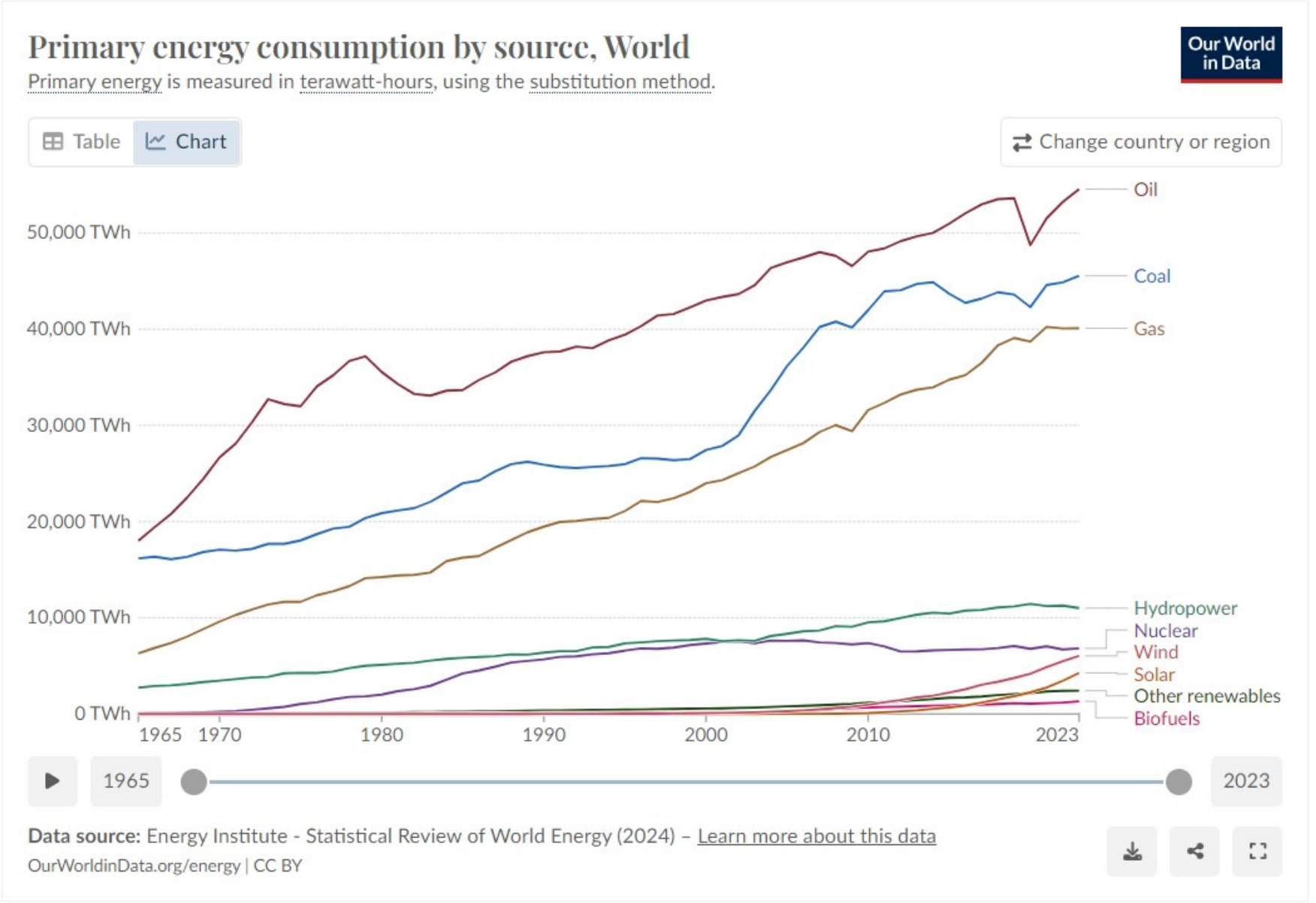
Energy Trends:
Sources, Past, Present and Future

Energy sources & distribution (2022)



- **80%** is still from **fossil fuels**
- **13%** is from **renewable sources**.
- Nearly **60% of this 12% came from modern renewables** (i.e., biomass, geothermal, solar, hydro, wind, and biofuels) and the remainder from traditional biomass (used in residential heating and cooking in developing countries).

Primary energy outlook, 2023

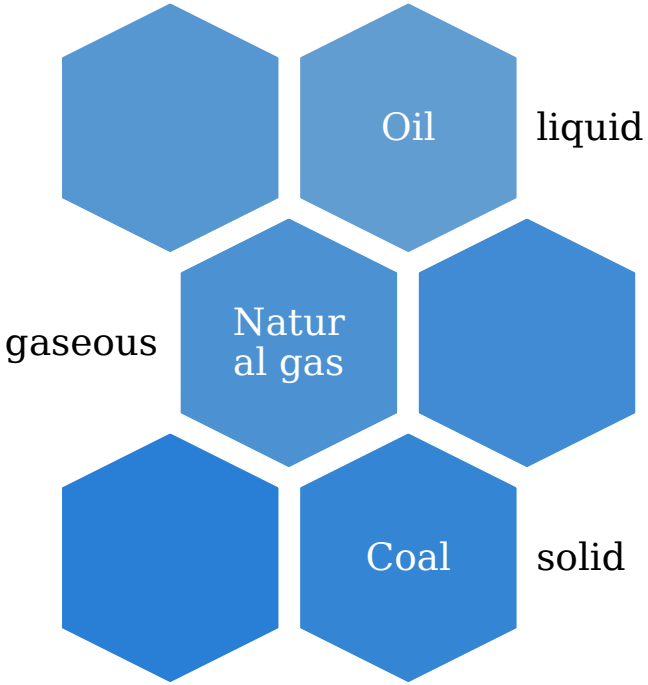


Energy Trends:
Fossil Fuels, Past, Present and Future

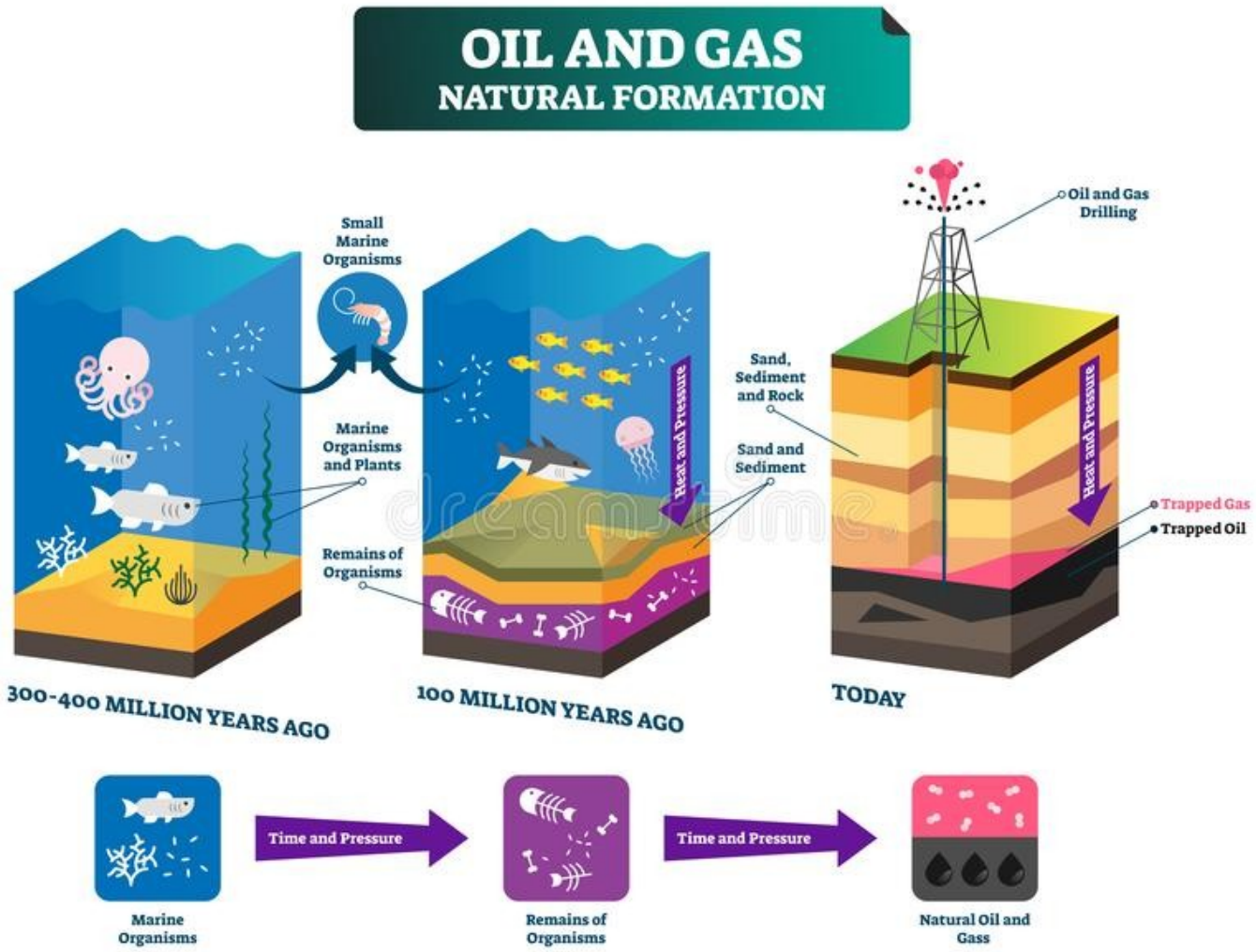
Overview of Fossil Fuels

The fossil fuels

- There are 3 main fossil fuels: oil, coal and natural gas
- They are called fossil because they were **accumulated from the fossil remains of animals and plants in past geological eras**.
- They are called fuels because they **react with O2 and energy sources to produce combustion**.
- Whether we like them or not, they were the energy fuels to sustain our development throughout the Industrial era and they are **still the main currently energy sources.**
- Harmful to environment, So **alternative recourses or improved technology** to reduce it is impact is something necessary to stope or reduce environmental impact.



The nature of fossil fuels



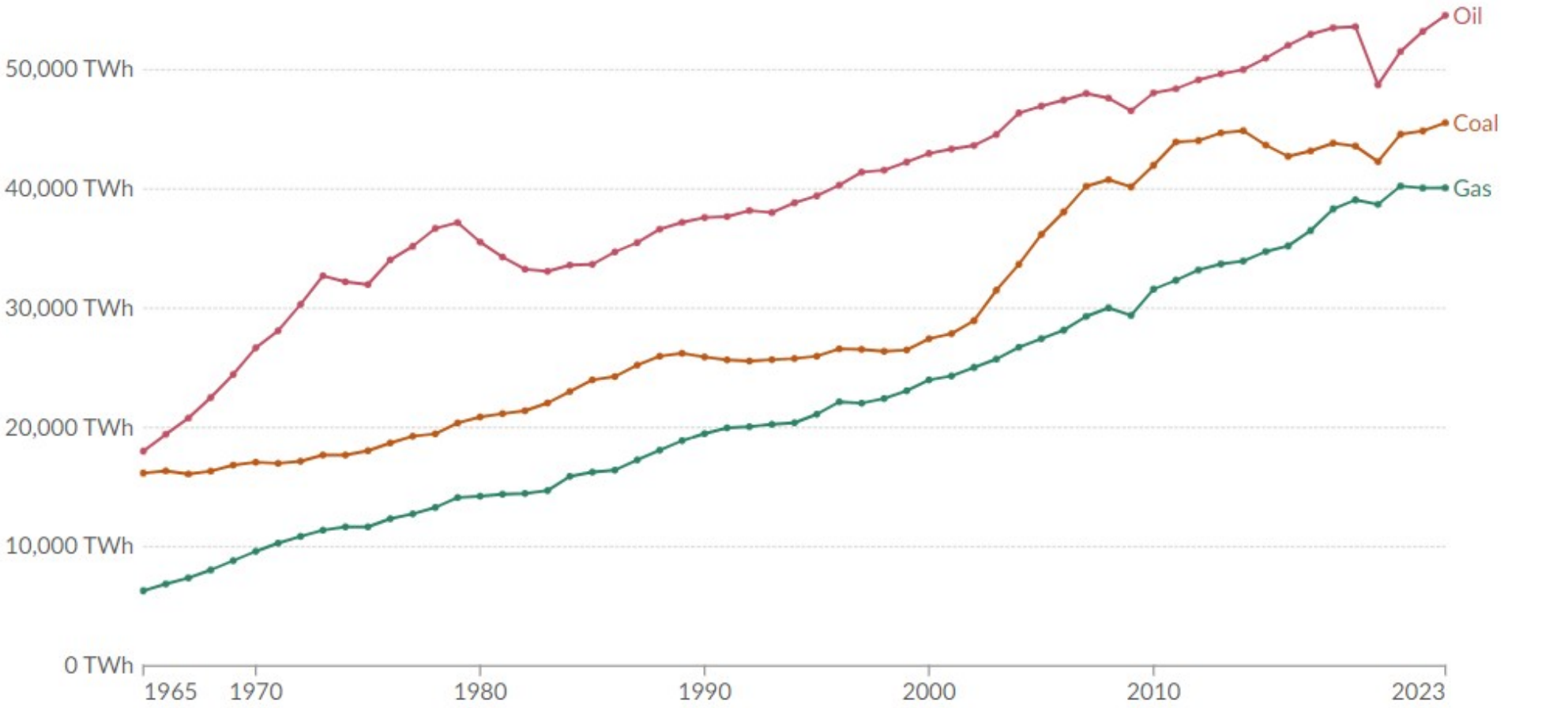
- The first thing we should know about them is that **they are finite resources**, exhaustible at some point in the future.
- The second is that they are **highly pollutant**.
- Their origin and nature is simple: **they are carbon energy resources accumulated of biological remains of distant past eras**. They were **buried for million of years**, representing large reservoirs of energy, but also, stocks of sequestered carbon.
- When we produce and consume them, we are consuming energy from past eras.
- And we are also releasing large reservoirs of carbon accumulations of distant past eras.
- They are UNSUSTAINABLE

Fossil fuel consumption, World

Measured in terawatt-hours.

Our World in Data

Table | Chart | Change country or region | Settings



1965 — 2023

Data source: Energy Institute - Statistical Review of World Energy (2024) – Learn more about this data

OurWorldinData.org/fossil-fuels | CC BY

Advantages of fossil fuels

Energy density:

FFs are globally used because of the large quantities of energy they release from a small volume of any of them. For instance, how many miles may you go with one liter of gasoline?

Low productive costs: until very recently, producing coal, oil and gas was extremely cheap. Indeed it is still, but as the shallower and less challenging reserves are depleted, costs are increasing with other resources (unconventional).

products and services:

The products from the refining of oil and natural gas are based on industrial processes known for decades, with affordable costs for the demand and well commercialized in all the aspects of our life. It is the same with the energy services we can get from them (power, heat, transportation, home

Infrastructure and technology:

Fossil fuels have been used for decades. Both the infrastructure to explore, discover and produce is already in place, the technology that makes it possible is very mature and enhancing with time.

Coal

- Composition (variable): C-H-O-N-S
- **Solid state, black appearance**.
- Types: anthracite, lignite, bituminous.
- Uses: industrial, electricity, heating.
- **Originated from fossilized terrestrial plant material**
- History as FF: in the past the most widely used, remains highly important and strongly linked to the increase of FF worldwide (China, India, etc.)
- **The most pollutant of all FF and with a high contribution to releases of CO2**.
- Its future is highly constrained due to environmental commitments.
- Used on the Medieval China around the 12th century
- **Widely used as fuel for ships and trains as well as industrial activities during the XIX century**.
- **However, it is still largely used as the 2nd source of global primary energy**, in developing nations for power, industrial activities, etc.

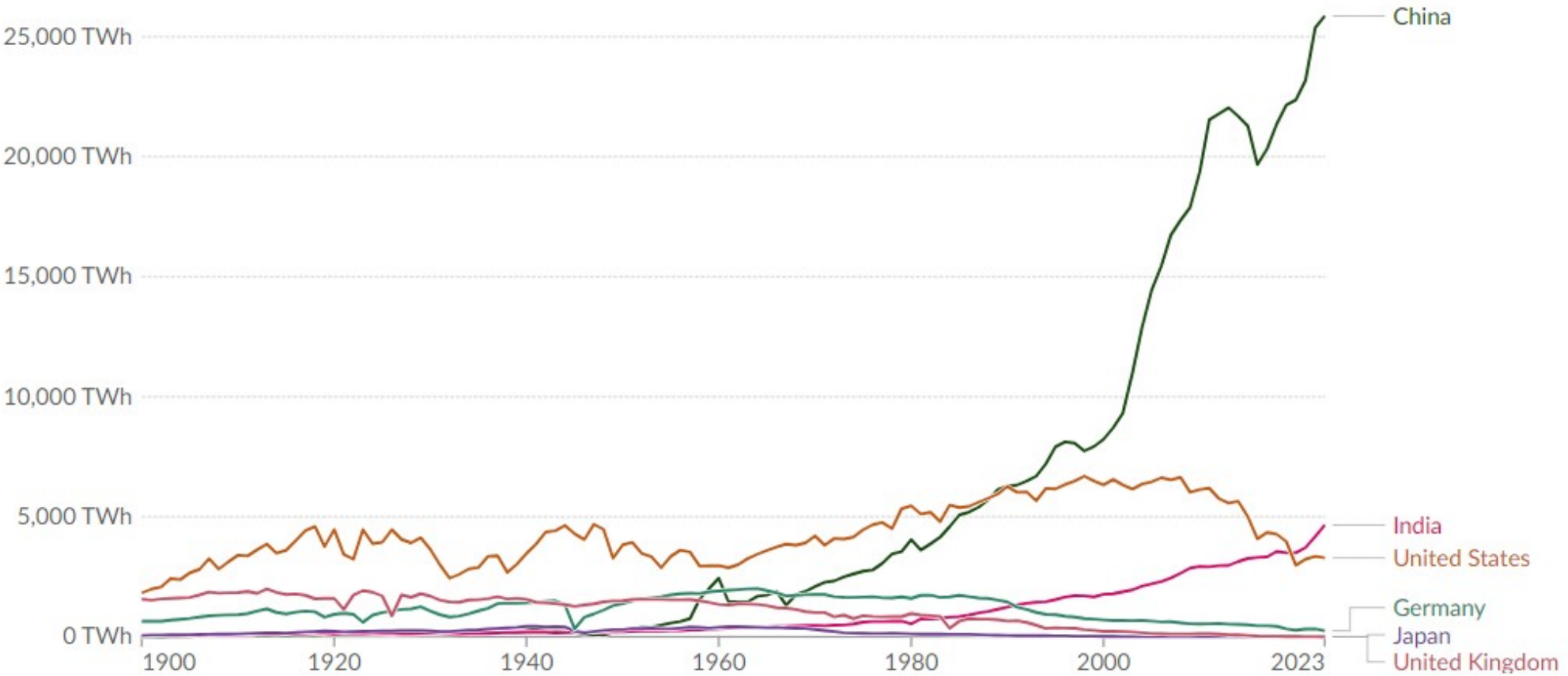
Coal production

Measured in terawatt-hours.

Our World in Data

Table | Map | Chart

Edit countries and regions



1900 2023

Data source: Energy Institute - Statistical Review of World Energy (2024); The Shift Data Portal (2019) – Learn more about this data

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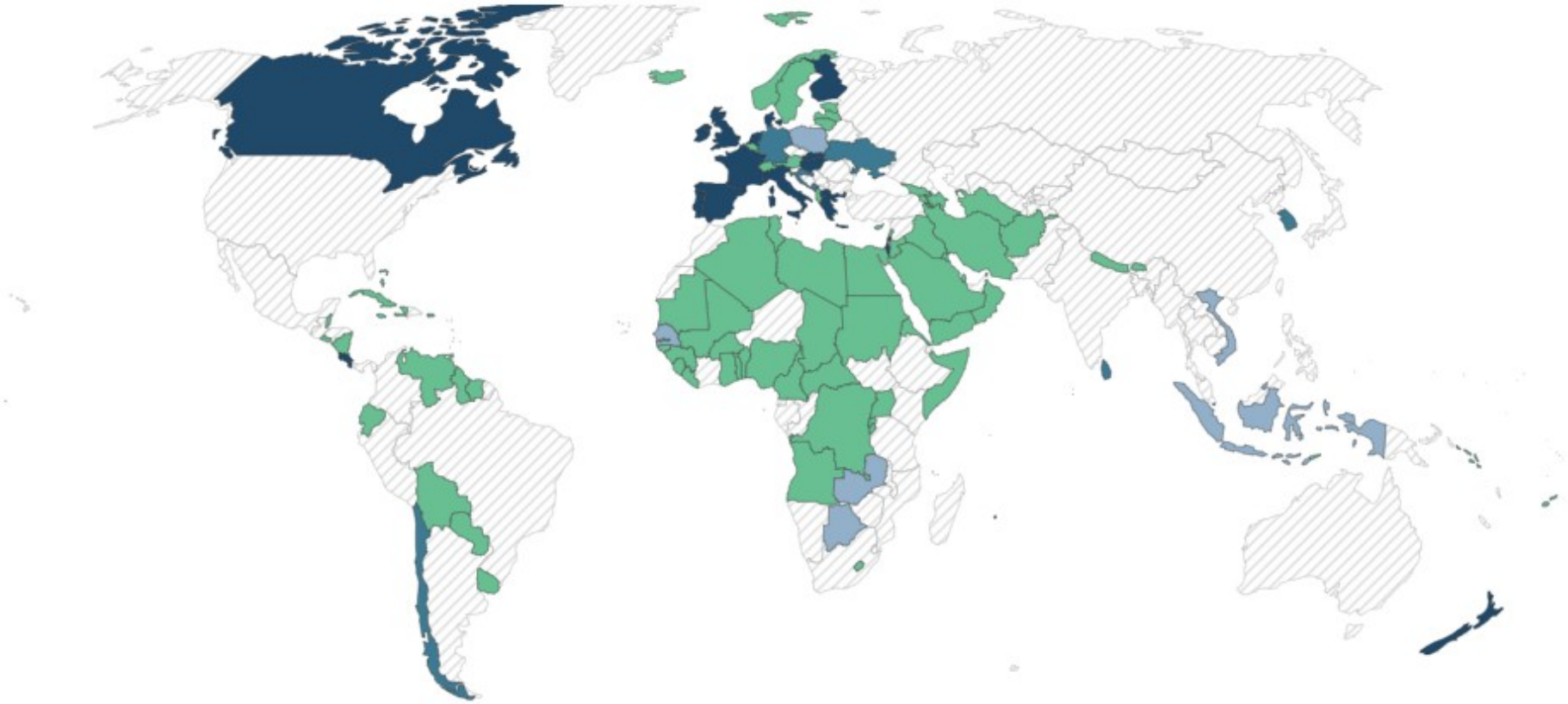
When will countries phase out coal power?

This measures pledges to phase out coal from the electricity mix.

Our World in Data

Table | Map

World



Coal free | Phase out by 2030 | Phase out by 2040 | Phase out in 2040s | No pledge

Data source: Powering Past Coal Alliance; Ember; Beyond Coal EU; Bloomberg Coal Countdown and other sources – Learn more about this data

Note: Where a concrete phase out date is not defined, we have allocated the final year of the target decade. For example, "Phase out in the 2040s" is given a target date of 2049.

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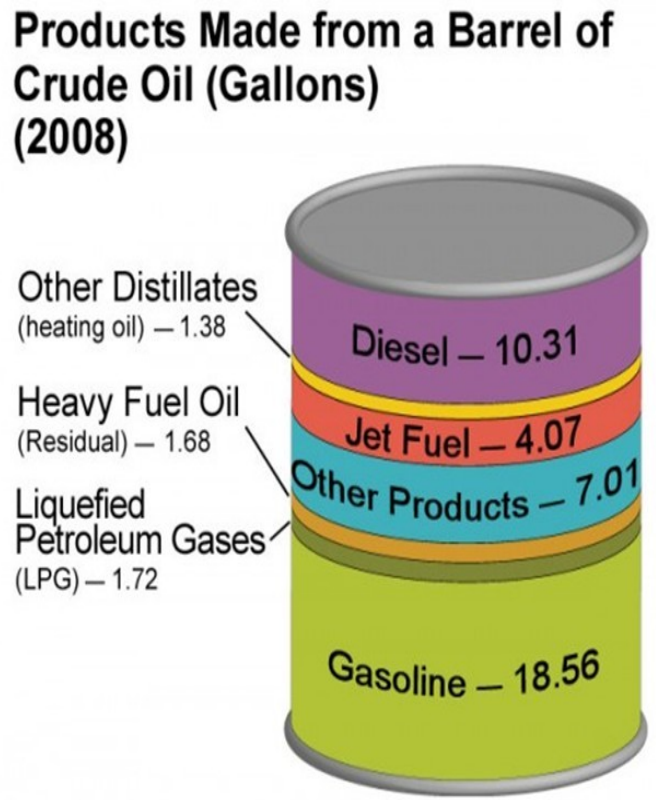
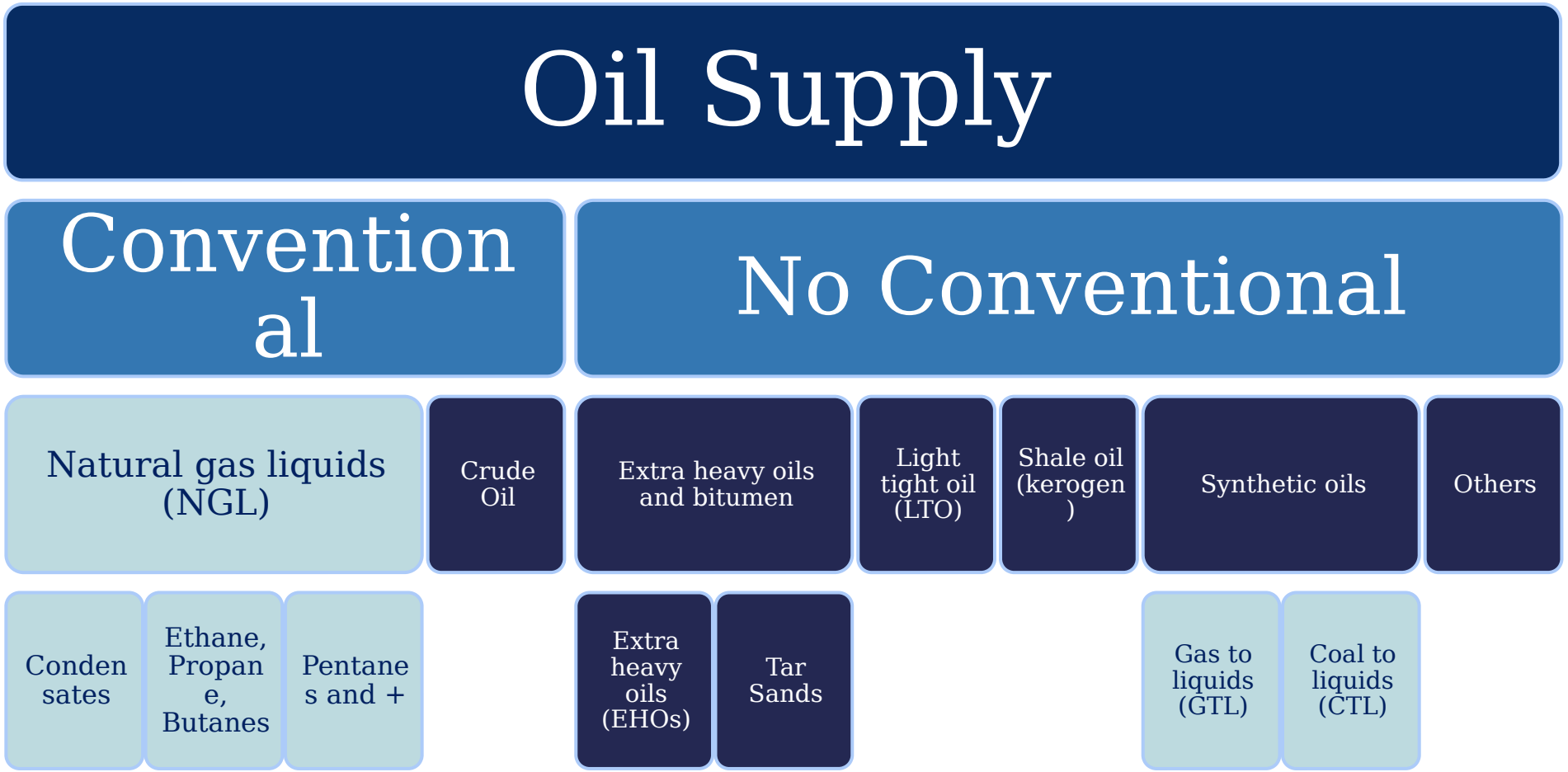
Oil

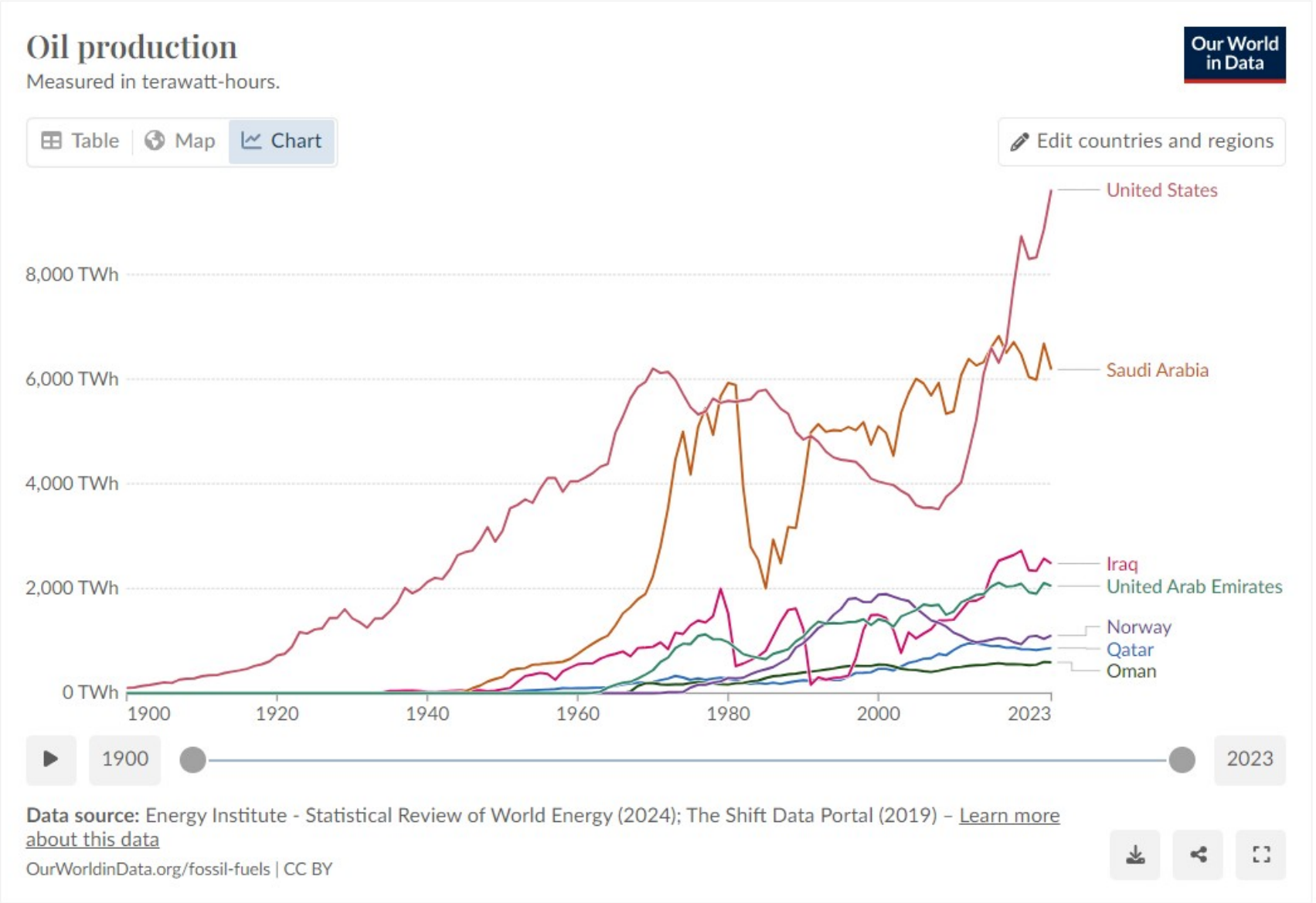
- Yellow to black liquid fuel found in geological formations.
- **1859: First oil well drilled PA, US by Captain Drake**
- **1920s-1930s: Giant oil fields are discovered in Middle East, turning it a critical geopolitical region**
- 1945-1973: Oil demand grows incredibly after development of American industry and chemistry
- 1973 & 1979: Supply oil shocks made the world aware of vulnerabilities of depending on oil.
- 1991: Iraq War, control of oil fields
- 1998-1999: bottom oil prices, depressed industry
- 2005-2020: new oil supplies come online from unconventional fields in the US.
- **2008 Peak oil price and economic downturn**
- After 2014: relative low prices in the world



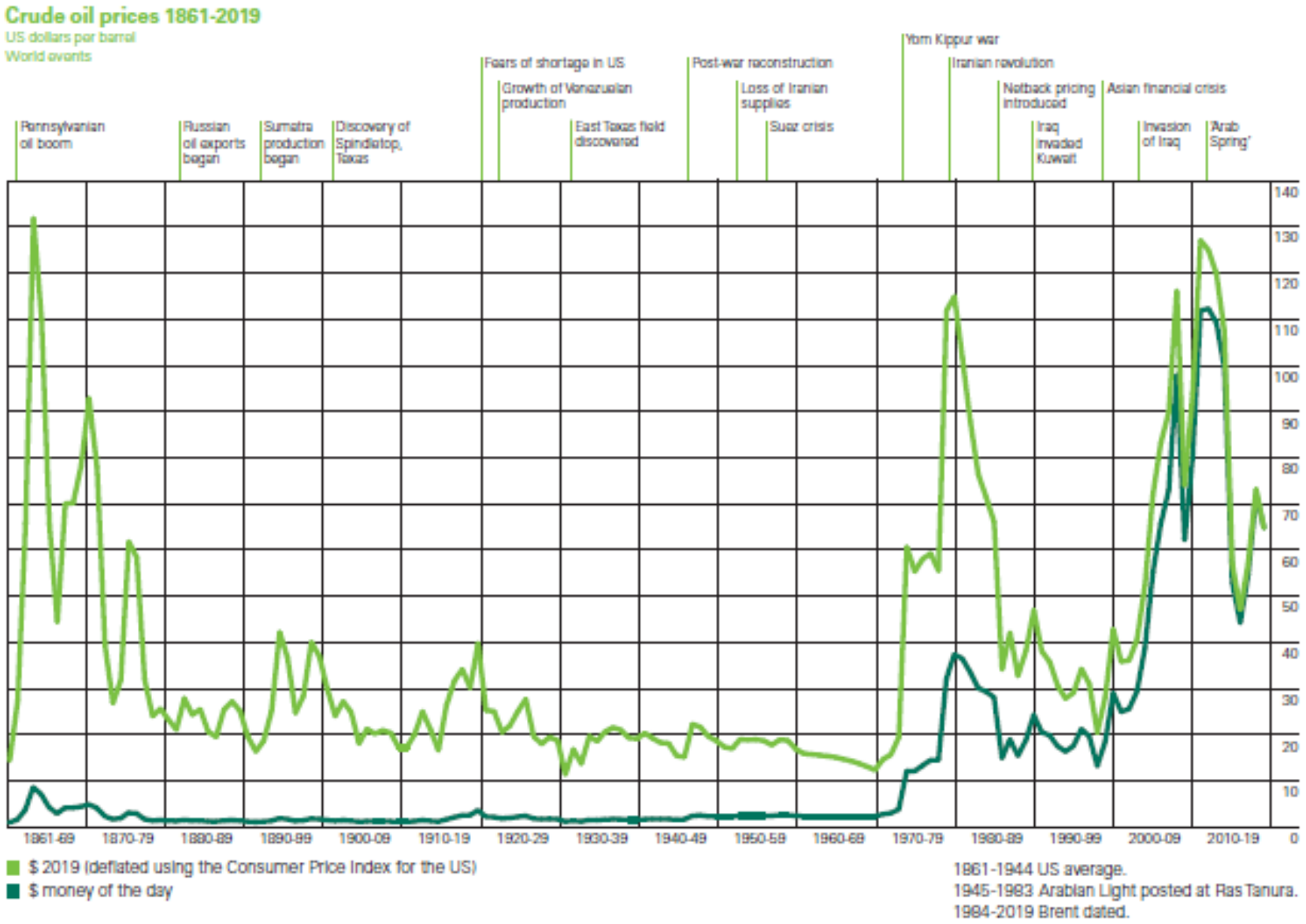

Oil Supply
Conventional
No Conventional
Natural gas liquids (NGL)
Crude Oil
Extra heavy oils and bitumen
Light tight oil (LTO)
Shale oil (kerogen)
Synthetic oils
Others
Condensates
Ethane, Propane, Butanes
Pentanes and +
Extra heavy oils (EHOs)
Tar Sands
Gas to liquids (GTL)
Coal to liquids (CTL)

- **Middle East is still the dominant production/supplier region.**

- The last 10 years have accounted a dramatic increase on the North American (US) production out of the US shale boom
- Ex URSS countries (CIS) are also increasing their output.
- In general, we are still increasing our absolute quantities of oil production.



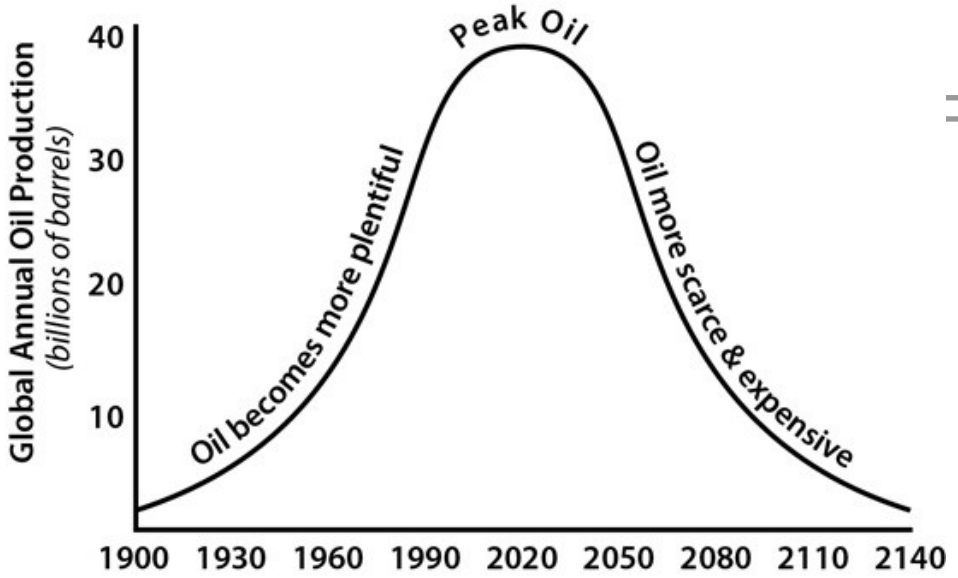
Crude oil prices through history

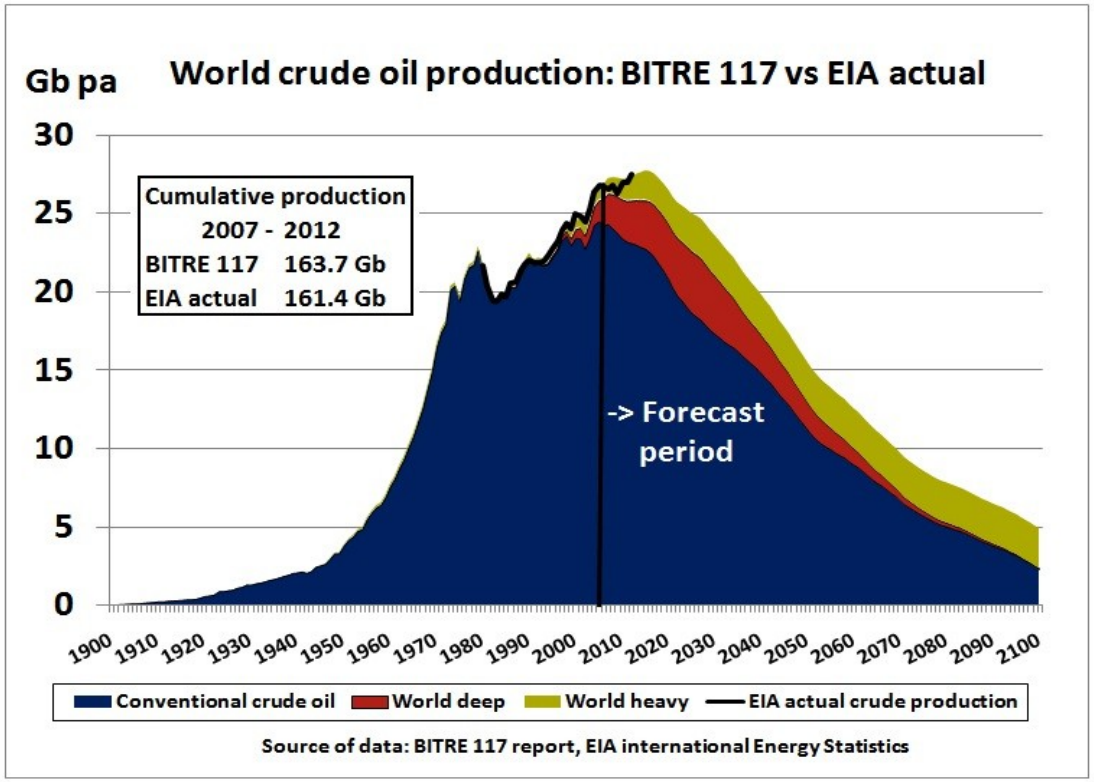


- **Crude oil prices always linked to major global events in the last 150 years.**
- In times of political crisis, disputes, wars, oil prices skyrocket very high.
- **In turn, when there are economic downturns or large production periods, oil prices depress.**
- In general, when oil resources start to dwindle, prices will soar

Peak oil

- As a non-renewable resource, there is a limited resource quantity of oil.
- **We are not sure with certainty of how much in total it is out there, but we are sure it is limited.**
- Thus, sometime in the future, oil production will peak and then decline.
- That is known as peak oil, a model proposed M. King Hubbert. It applies likewise to any mineral resource with finite quantities.
- **It is forecasted that the world oil production would peak somewhere between 2005 and 2025. However, new technological developments and new resources may change such date.**
- **Once reached the peak, production would decline, supply too and prices start to rise.**
- So, even before oil becomes depleted, prices and stocks would turn it non-commercial





Oil Market

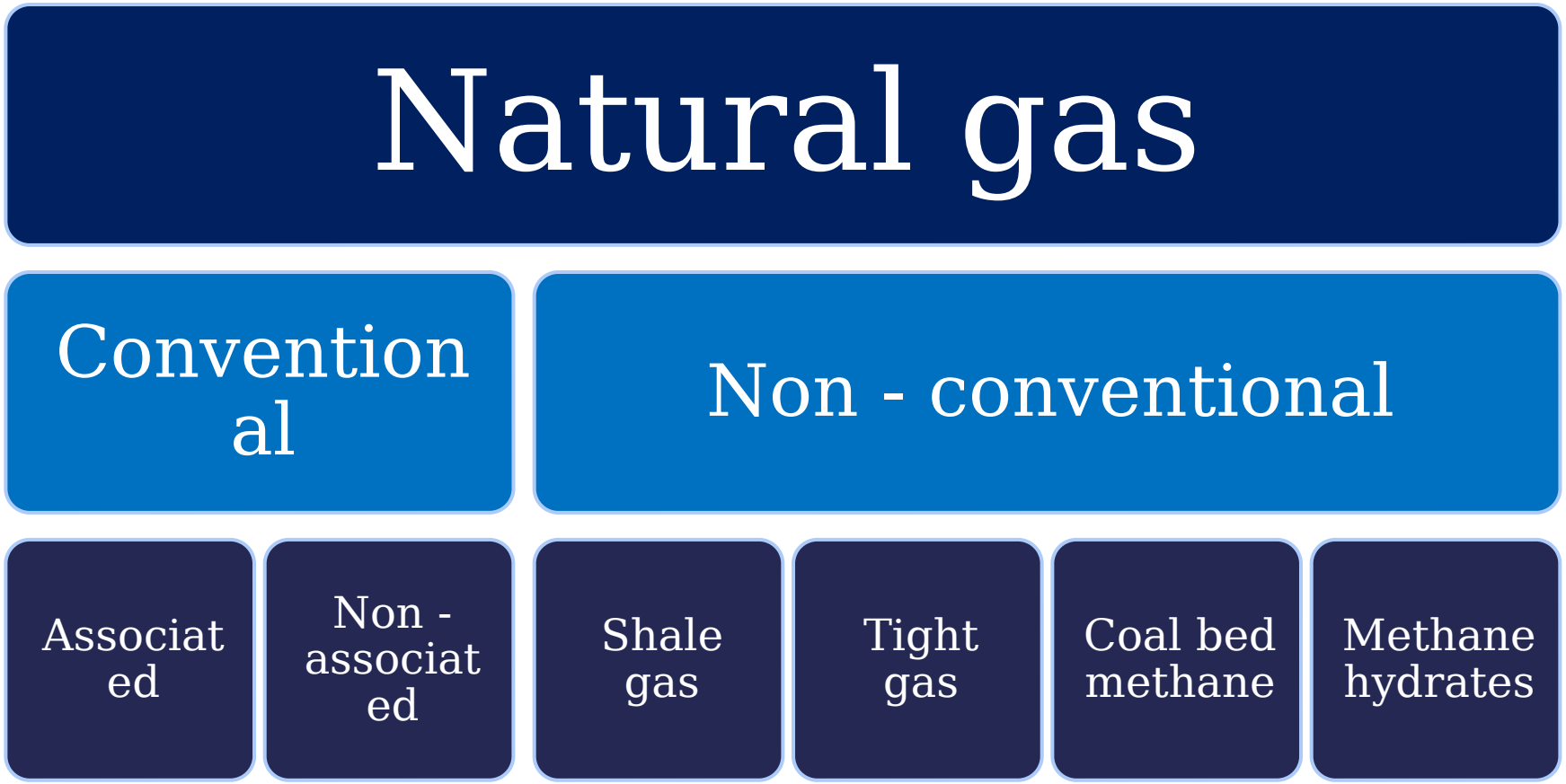
- Significant Drop in Oil Prices
  - Oil prices have dropped to around $70 per barrel
  - Trend observed as of September 2024
  - Prices were higher earlier in the year

- Global Demand for Oil
  - Forecasted to be 104.46 million barrels per day in 2024
  - Increase from 102.21 million barrels per day in 2023
  - Significant decrease in consumption in China
  - Overall demand expected to rise by 900 thousand

Natural gas

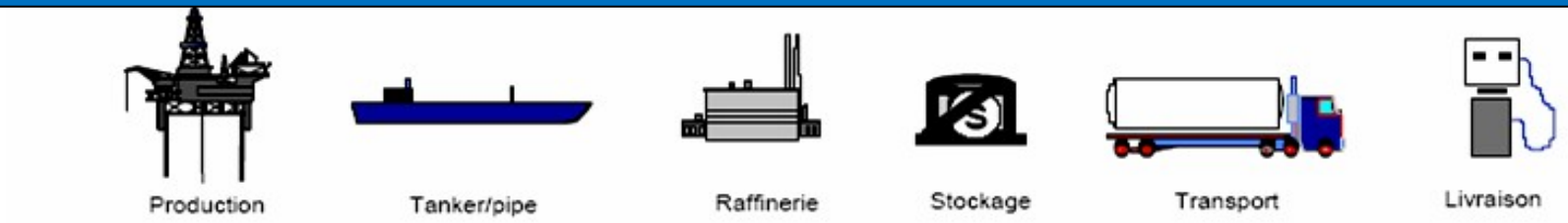
- **The cleanest of all fossil resources**
- **25% of global energy consumption**
- **The energy resource with the highest growth.**
- **Mostly formed of methane (CH4)** in great percentage, ethane, propane and traces of larger hydrocarbons
- **Possible replacement of oil / coal and transition resource toward cleaner energies.**
- However, the difference comes from the depth: Biological deposits at deeper layers are subject to higher pressures and temperatures, breaking them down and turning them into simpler hydrocarbons
- Initially used for Town gas and gas lamps.
- **Associated with the oil production, it was initially treated as product and vented or flared.**
- **First long-distance pipeline in 1925 – USA**
- 1930's: development of high resistance steel for pipes
- After the 50's: major NG discoveries.
- **1969: first LNG cargo from Algeria**
- 1980s: LNG market starts growing
- **1996-97: Qatar first LNG shipment**

Natural gas sources

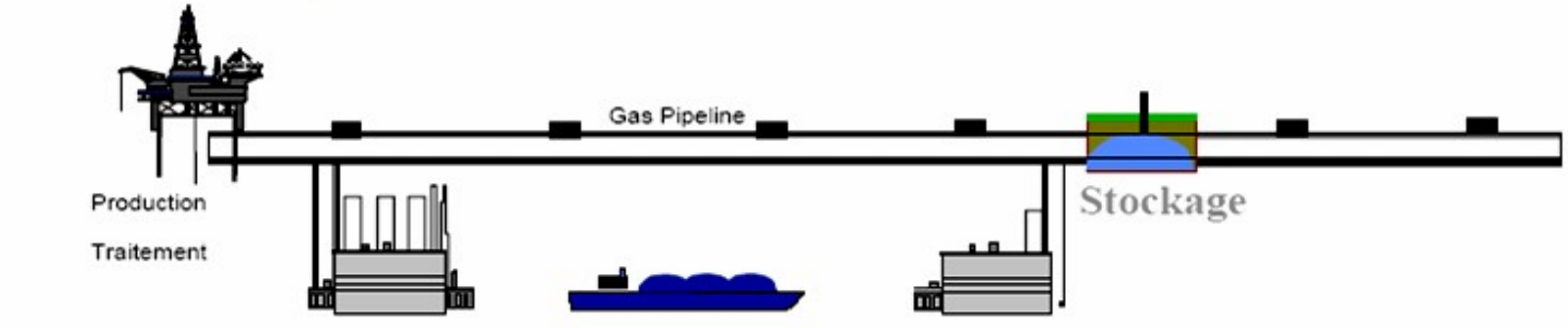


Oil & Gas: two radically different commodities

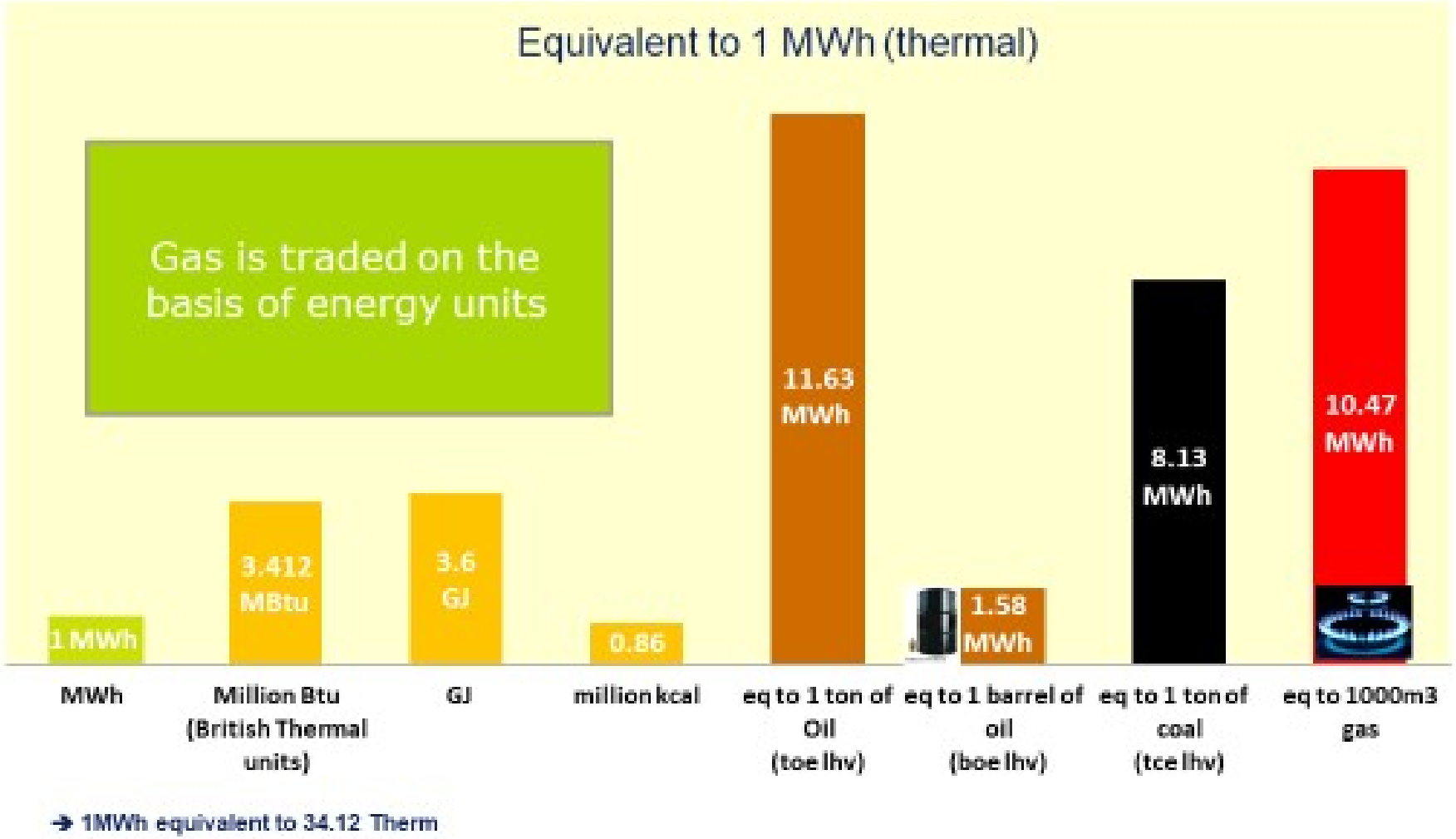
Oil is liquid: easy and cheap to ship, store and move



Gas (CH4) is gaseous!...complex and costly to ship & store



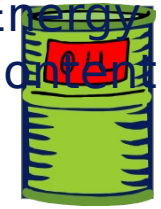
Gas Units



➔ 1MWh equivalent to 34.12 Therm

The problem with gas is its bulkiness

1 barrel of oil's Energy content



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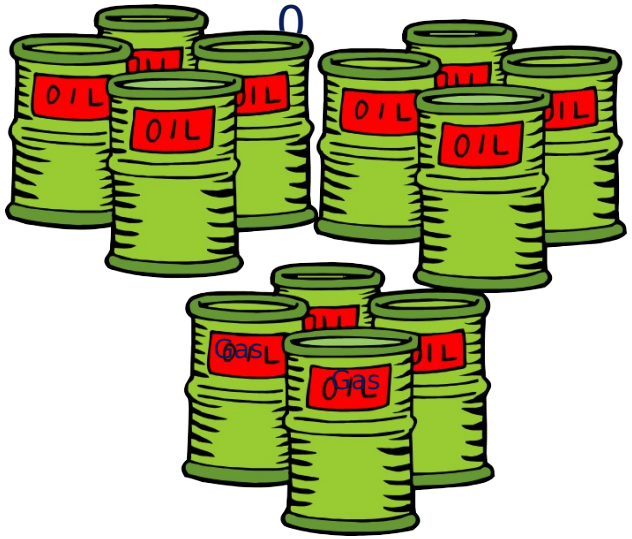
1030 « barrels » of gas's Energy content



~1.5 « barrel » of LNG's Energy content

Cooling

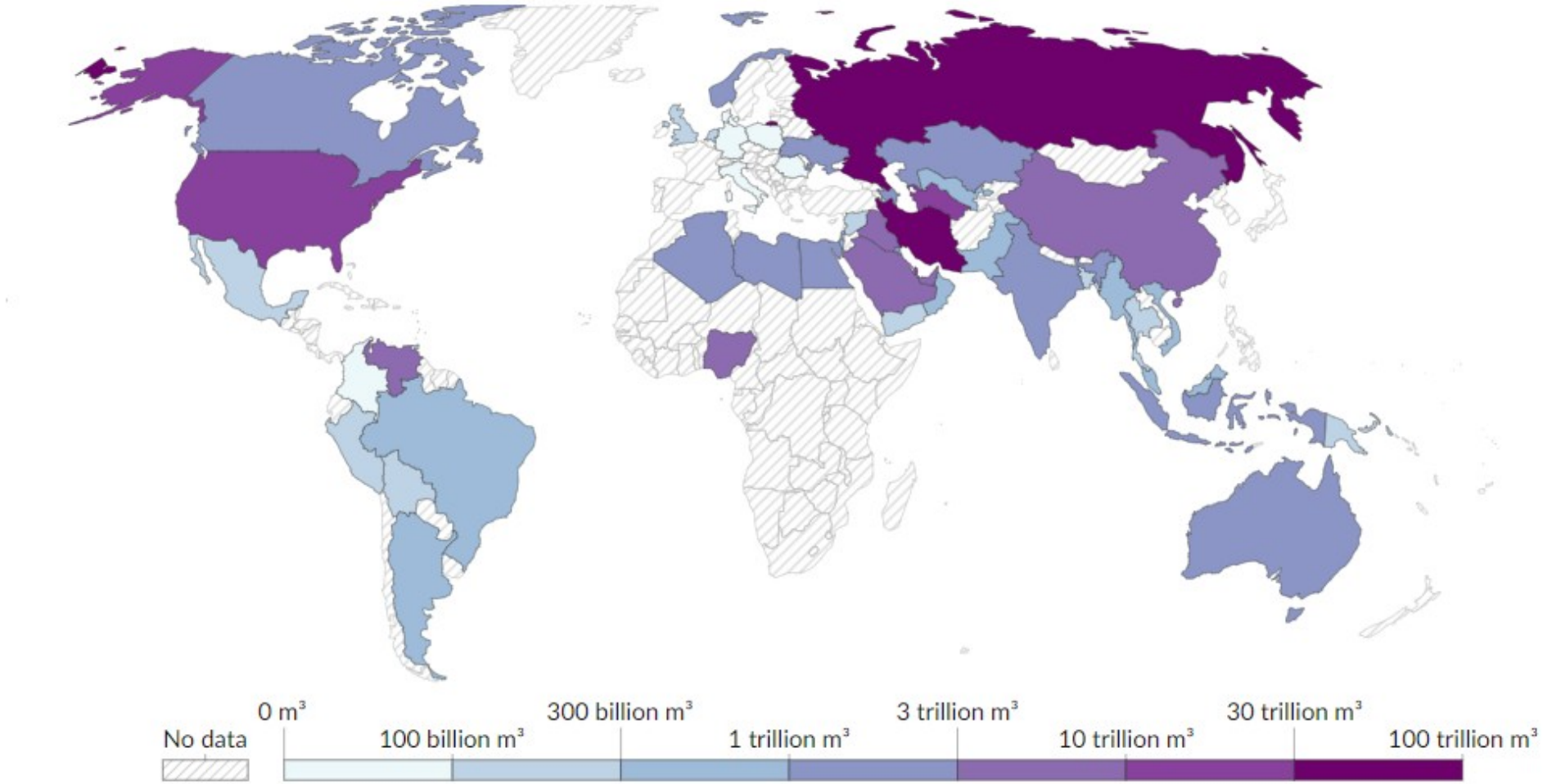
Gas reserves, 2020

Proved reserves, measured in cubic meters, are generally those quantities that can be recovered in the future from known reservoirs under existing economic and operating conditions, according to geological and engineering information.

Our World in Data

Table | Map | Chart

World



Data source: Energy Institute - Statistical Review of World Energy (2024) – Learn more about this data

OurWorldinData.org/fossil-fuels | CC BY

World gas conventional proven reserves

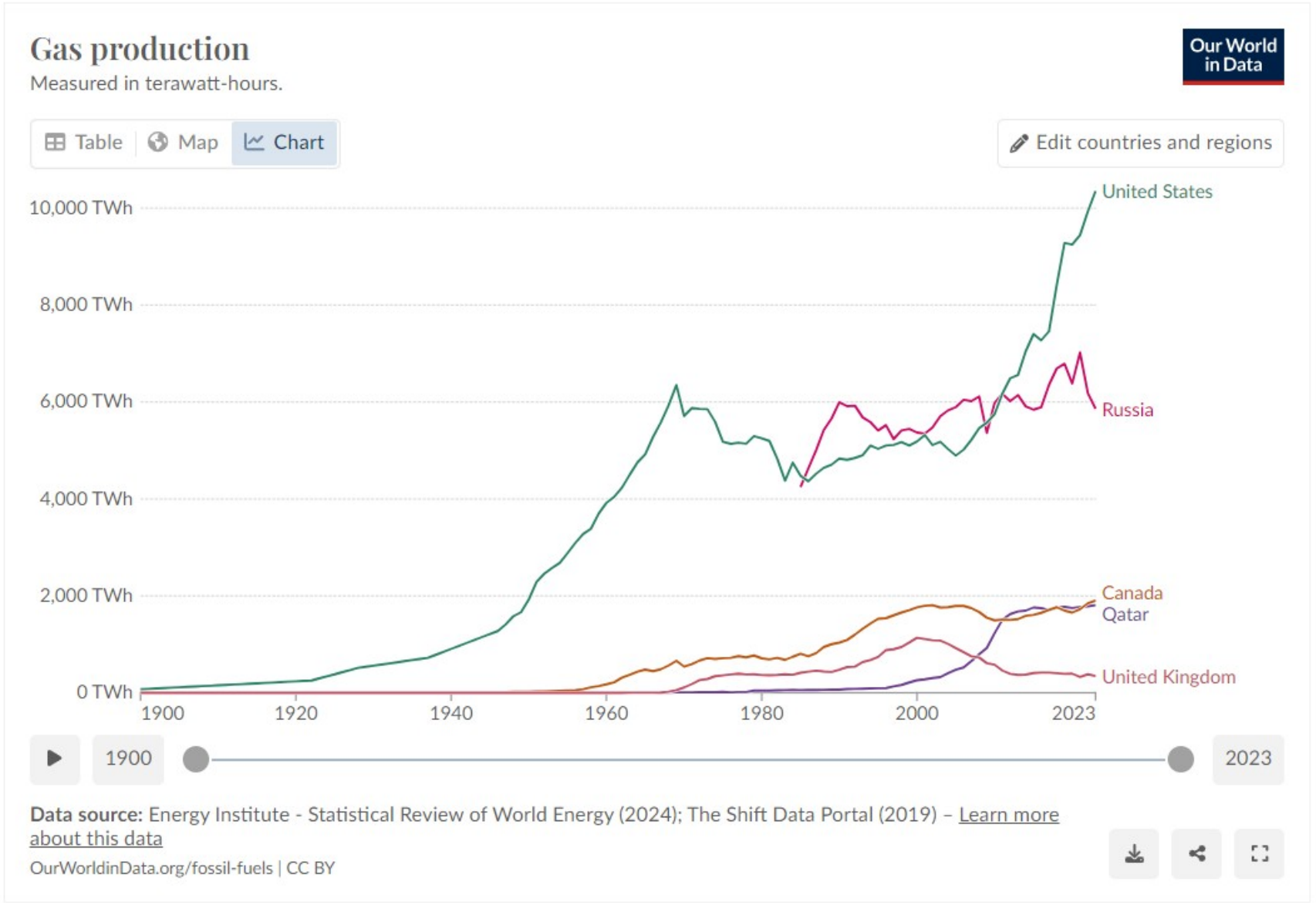
- Between 180 to 200 TCM
- Twice the amount produced so far.
- More than 50 years at current rates.
- Increase in discoveries since the 60’s
- However, they are now harder to find
- Geographically uneven distributed

Qatar has the third largest proven reserves of natural gas. Proven reserve of natural gas of **25,000 Bm3** (850 TCF).

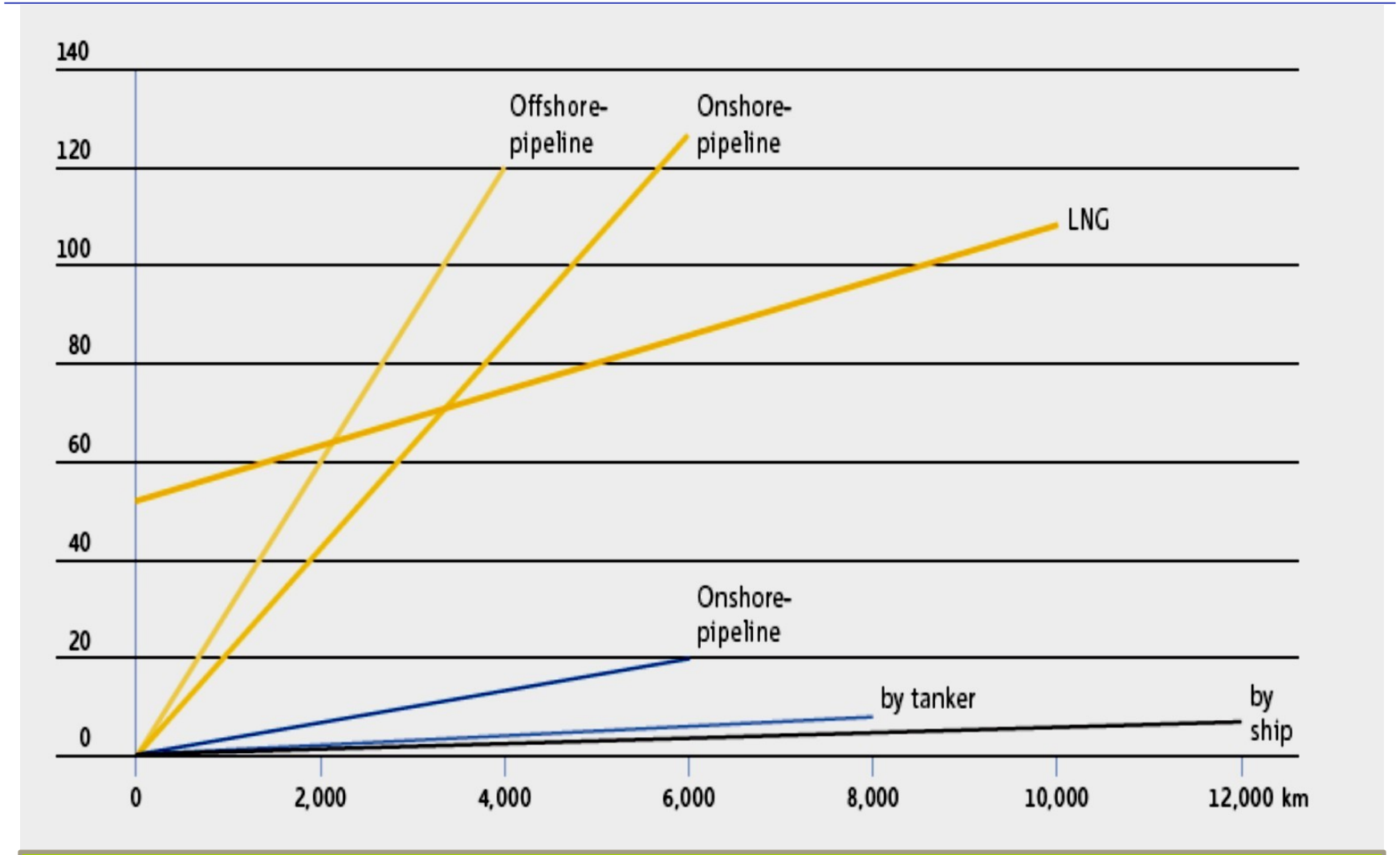
Country	Reserves	%
World	192.24	100
Russia	47.77	24.9
Iran	33.59	17.5
Qatar	25.19	13.1
Saudi Arabia	8.15	4.2
USA	7.73	4
Turkmenistan	7.50	3.9
UAE	6.08	3.2
Venezuela	5.52	2.9
Nigeria	5.15	2.7
Algeria	4.50	2.3
China	3.51	1.8
Iraq	3.17	1.6

Quantities in Trillion cubic meters (TCM)

- Global gas production is growing more steeply on the last years
- **North America and the Ex USRR are historically the largest productive regions.**
- The last 15 years have accounted a dramatic increase on the North American production from the US shale gas boom
- **Middle East is growing in gas production steadily from countries like Qatar, Iran, KSA and others.**
- Asia Pacific is also increasing production.
- **Unlike them, Europe is decreasing.**

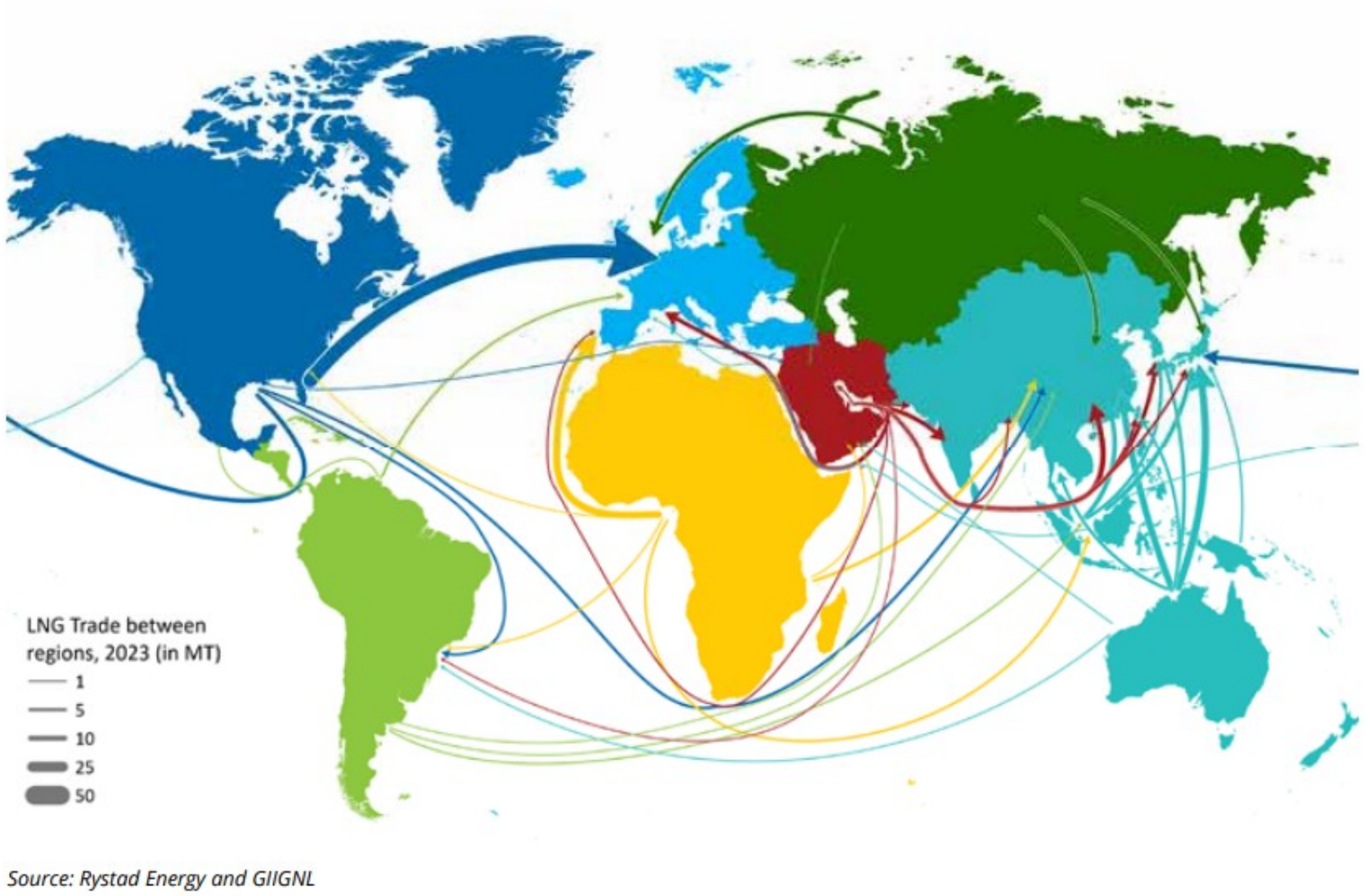


Costs incurred to transport primary energy sources in US$ per tonne of oil equivalent



The economics of gas are driven by its logistics

Gas trade movements - 2023



Source: Rystad Energy and GIIGNL

- **Gas is more difficult to trade than oil / coal because it is gas and requires pressure and other conditions**
- 2 major ways to transport natural gas: 1) pipeline; 2) LNG through vessels.
- Pipelines are used in major producers near consumers (the US, Russia, Europe).
- **However, it is LNG which is globalizing the gas market due to its flexibility, allowing overseas trade.**
- The major LNG exchanges are in the Asian Pacific basin and from Middle East to other markets.
- The major pipelines exchanges are between Russia and Europe and in North America.

Transmission Grid 1970
Around Groningen…

Source:
Fluxys

Transmission Grid 1980

First Soviet Gas...

Source:
Fluxys

Transmission Grid 1990

North Sea operations are on line…

Source:
Fluxys

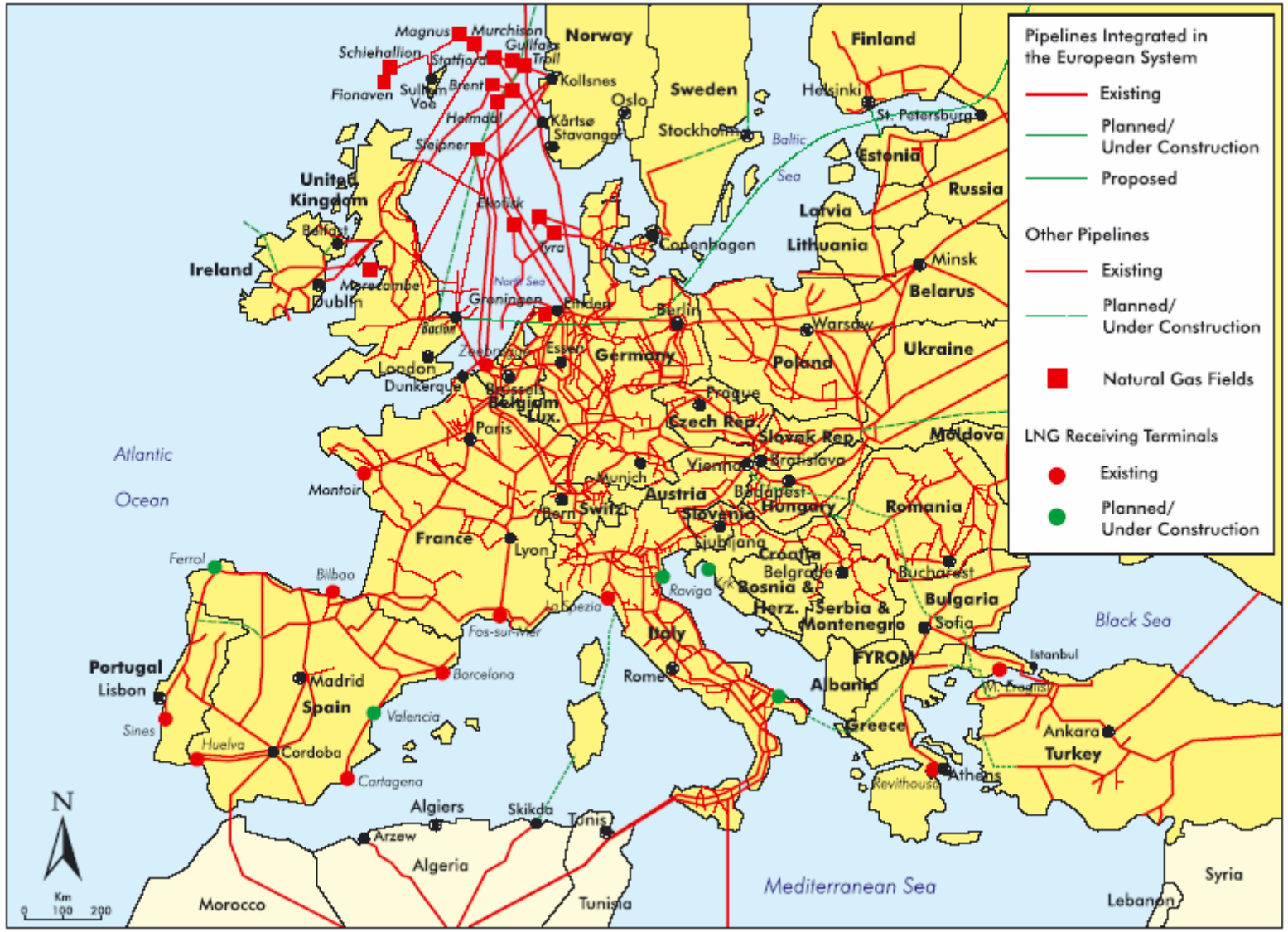
Transmission Grid 2003

More Russian and Algerian gas

Source:
Fluxys

Transmission Grid 2013

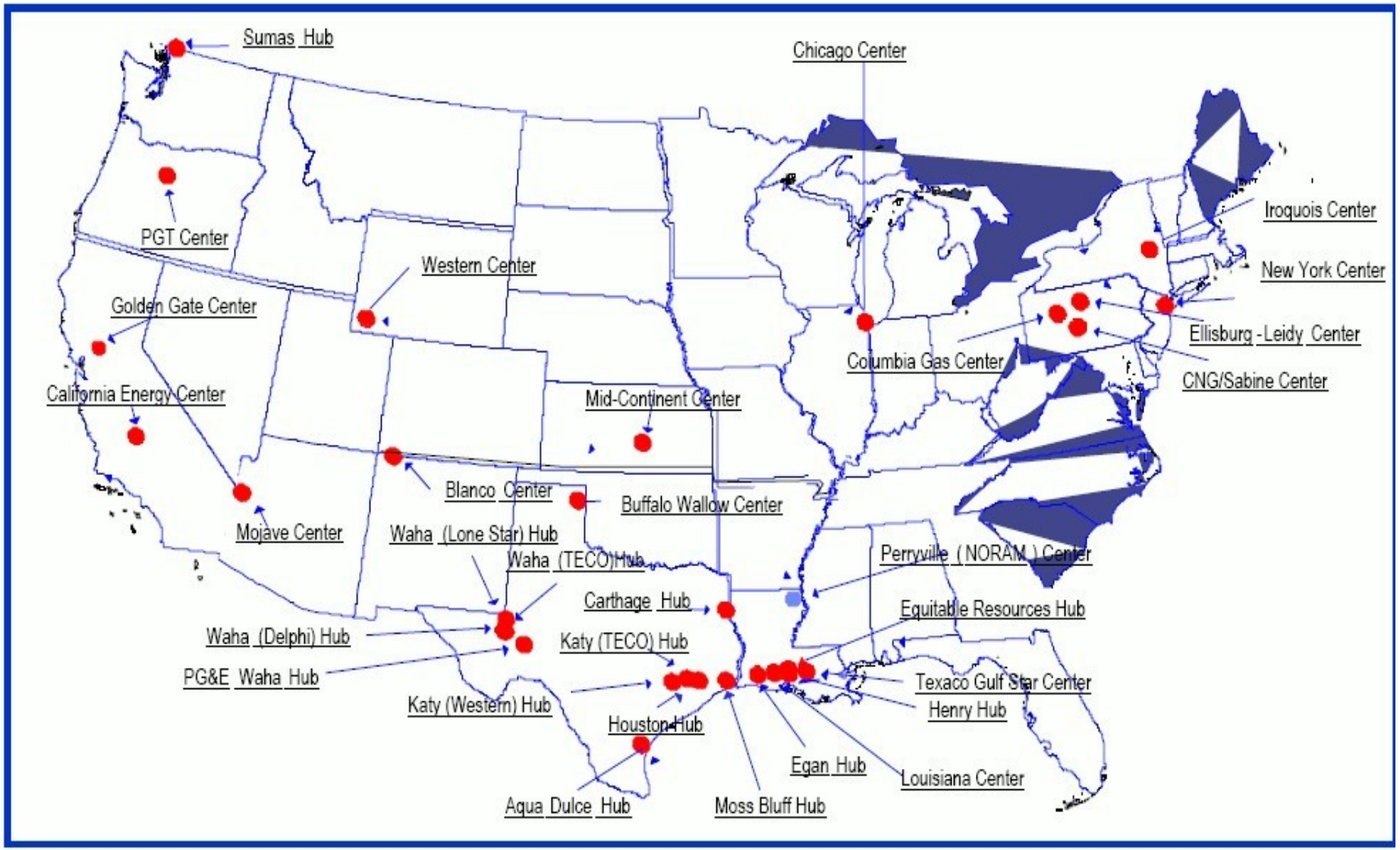
More Russian and Algerian gas



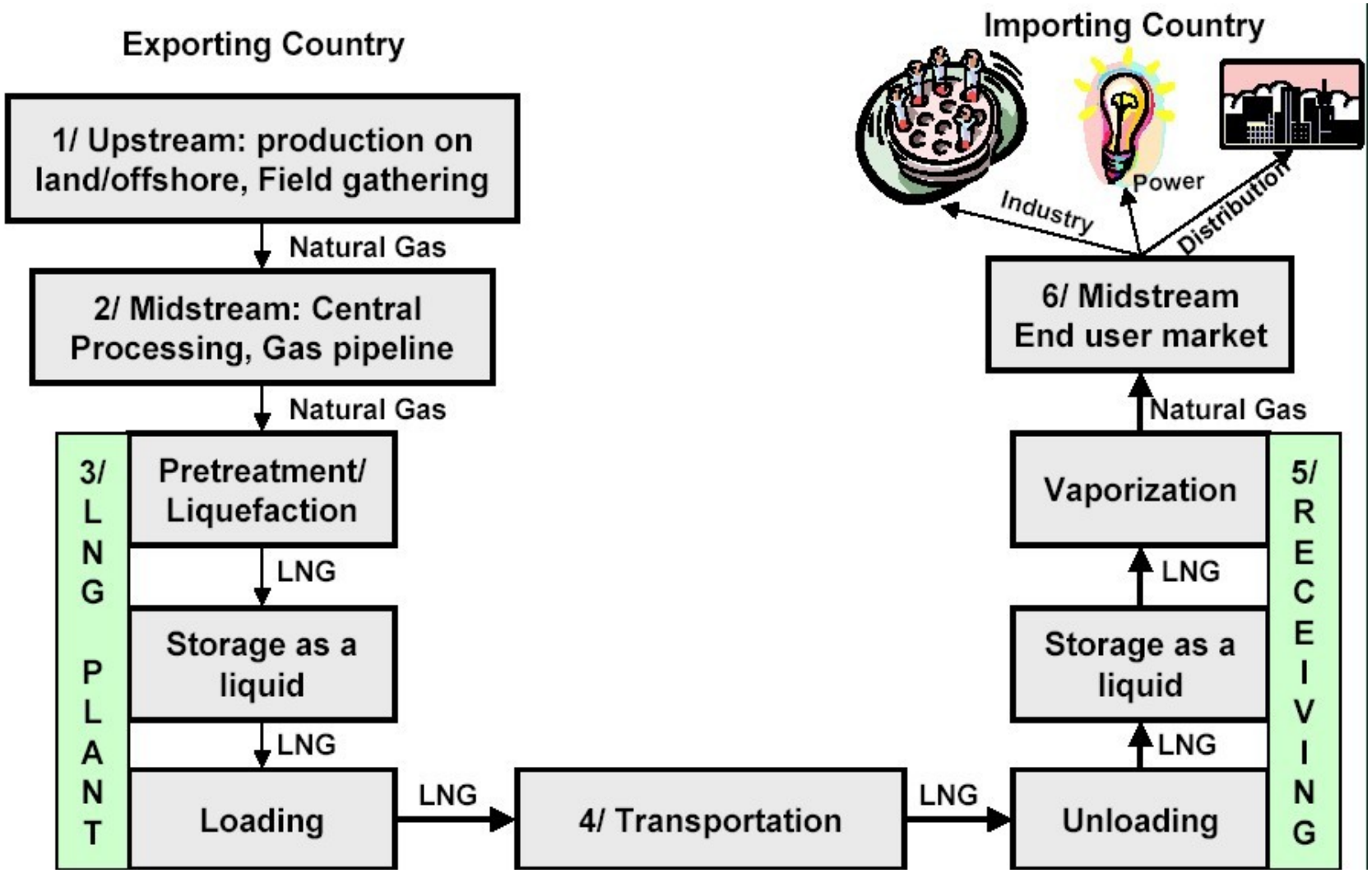
https://www.researchgate.net/figure/Figure-A-2-European-natural-gas-infrastructure_fig5_242448674 [accessed 1 Oct, 2023]

A fully liberalised market

US Gas Hubs

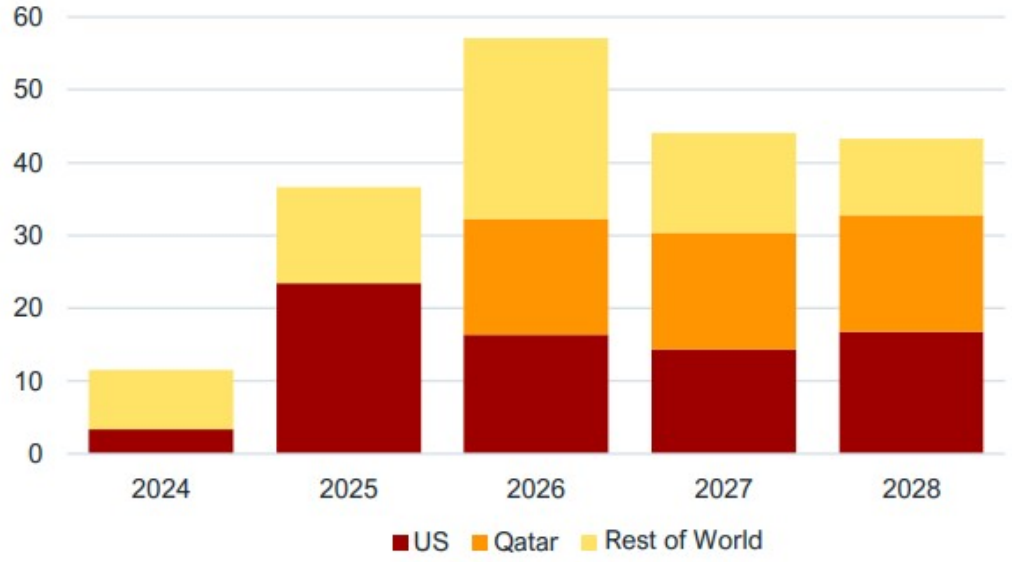


What is Liquified Natural Gas?
The LNG process



Qatar’s LNG

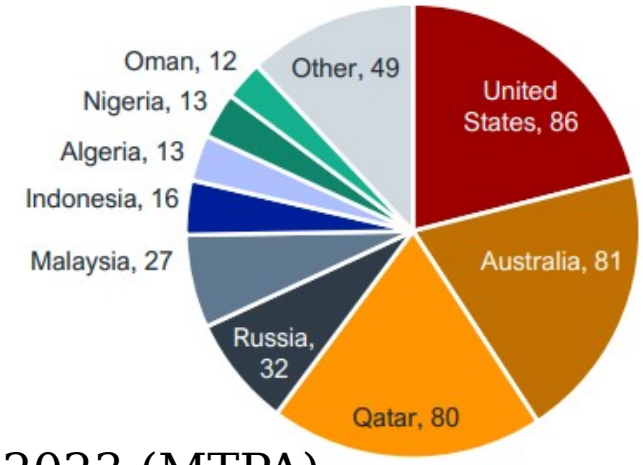
Qatar, the world’s leading LNG exporter prior to 2020 and the third-largest exporter in 2023.



Source: IEEFA estimates, based on data from the International Gas Union, the International Group of Liquefied Natural Gas Importers, Independent Commodity Intelligence Services, Kpler, Global Energy Monitor, company announcements and financial filings, and news reports.

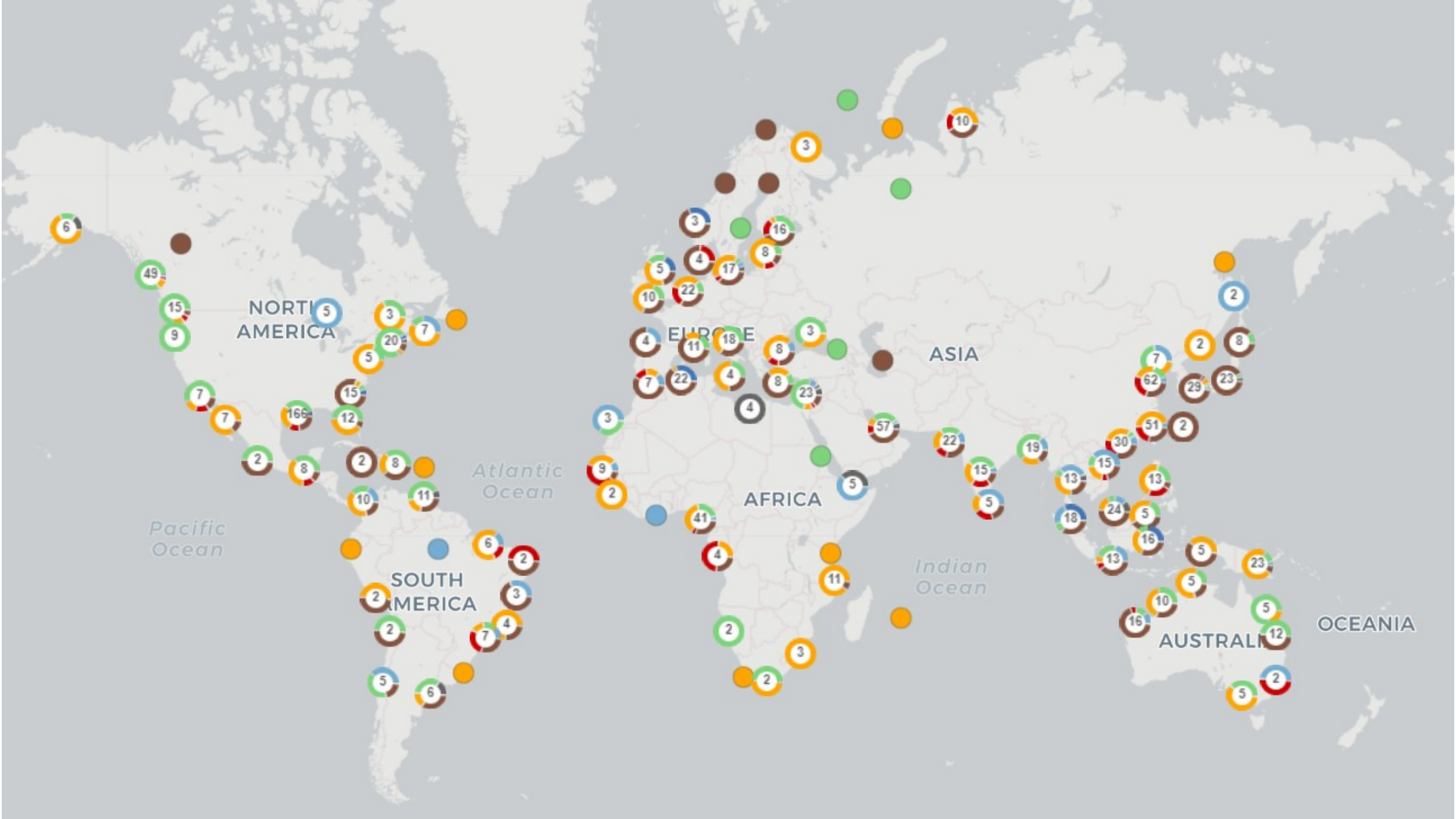
Global LNG Supply Additions 2024-2028 (MTPA

- The development of the North Field complex will boost Qatar’s liquefaction capacity by 64 MTPA through 2030.
- The first of the North Field trains is expected to come online in 2025 or 2026, with 48 MTPA likely to come online by 2028
- An additional 16 MTPA coming into service by 2030.
- Qatar’s LNG industry boasts the cheapest LNG production costs in the world, due
and liquid

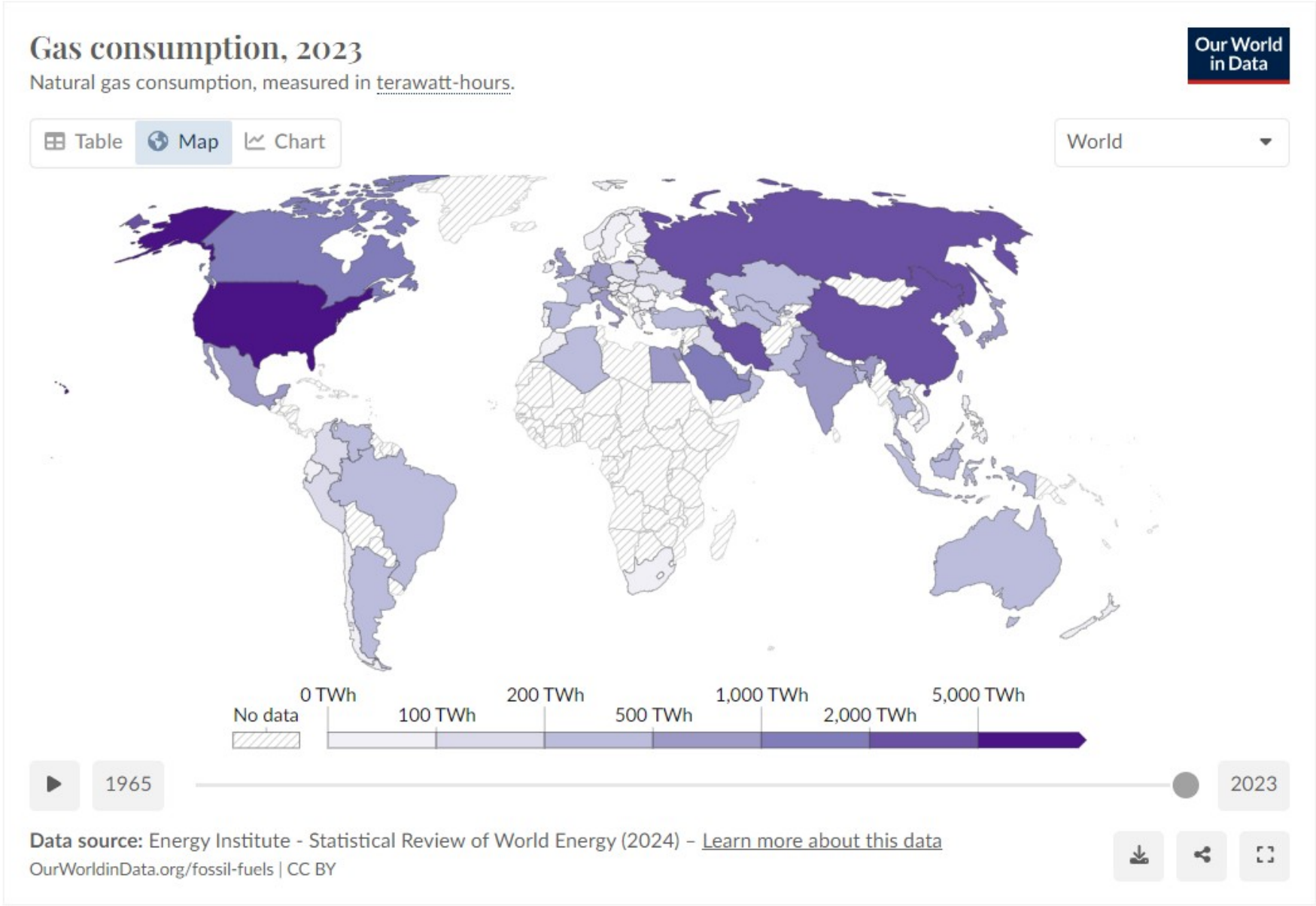


Global LNG Exports, 2023 (MTPA)

Source: IEEFA estimates based on Kpler data.

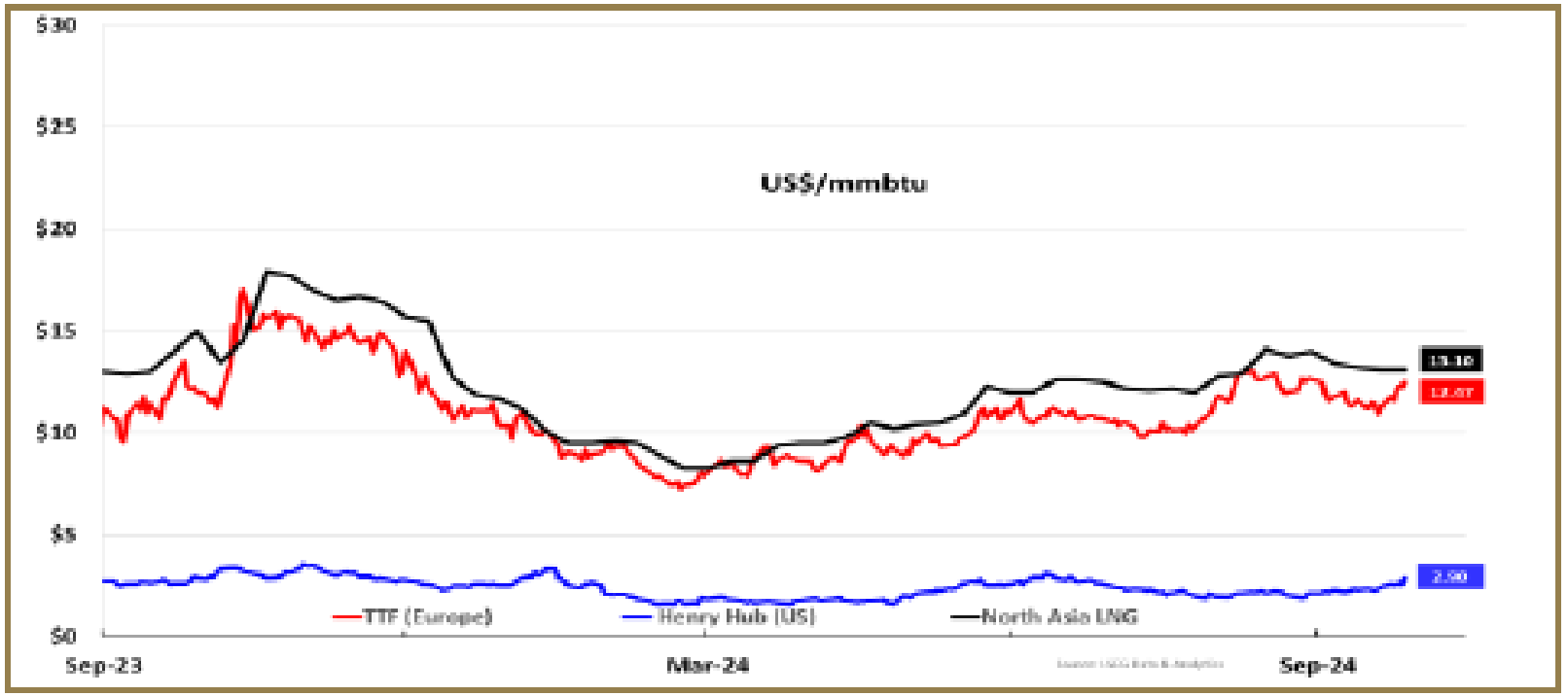

NORTH AMERICA
EUROPE
ASIA
AFRICA
SOUTH AMERICA
AUSTRALIA
OCEANIA
Atlantic Ocean
Pacific Ocean
Indian Ocean

- **North America is not only the largest producer, but consumer as well.**
- Asia Pacific and Middle East are also showing growing trends of consumption.
- **Thus, large producers are also large consumers.**
- Exception: CIS (Ex USRR) which is the largest gas reserve, but with steady consumption and plans to increase exports to other markets.
- **In general, gas consumption is increasing worldwide and we could expect fuel switching from oil and coal in future decades.**



The closing price ($/mmBtu) as of Friday 27 Sep 2024

Benchmark Gas Prices		
NE Asia LNG	Europe TTF	US Henry Hub
13.10	12.47	2.90
Weekly Change ▲ 0.0%	Weekly Change ▲ 10.7%	Weekly Change ▲ 19.2%
YTD Change ▼ 17.7%	YTD Change ▼ 14.3%	YTD Change ▼ 7.8%



NATURAL GAS MARKET DYNAMICS

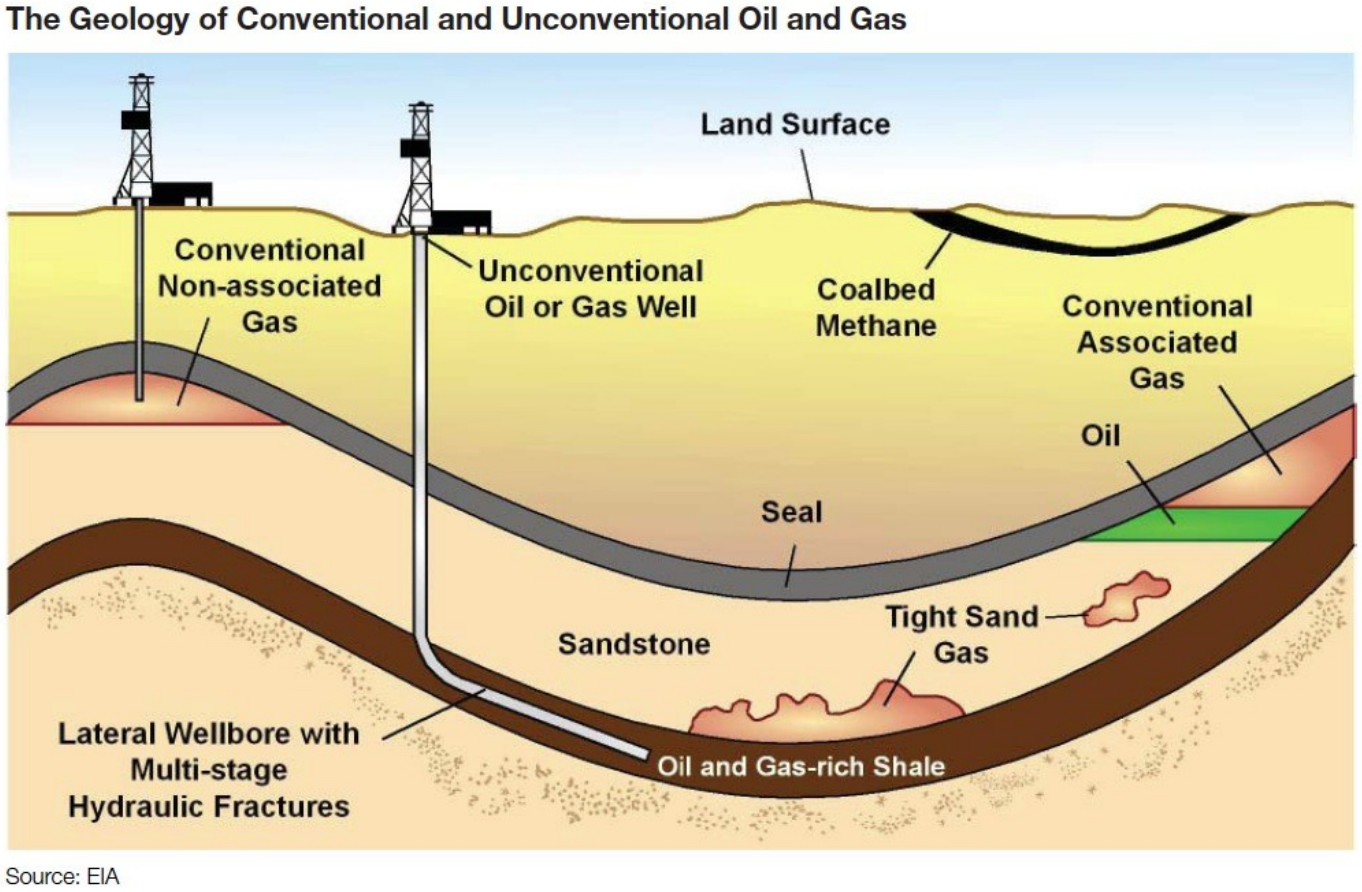
- Significant Role in Energy Market
  - Acts as a 'bridge fuel' in transition to renewable energy
- Steady Growth in Consumption
  - Driven by increases in LNG exports
  - Higher consumption in power generation

NATURAL GAS CONSUMPTION

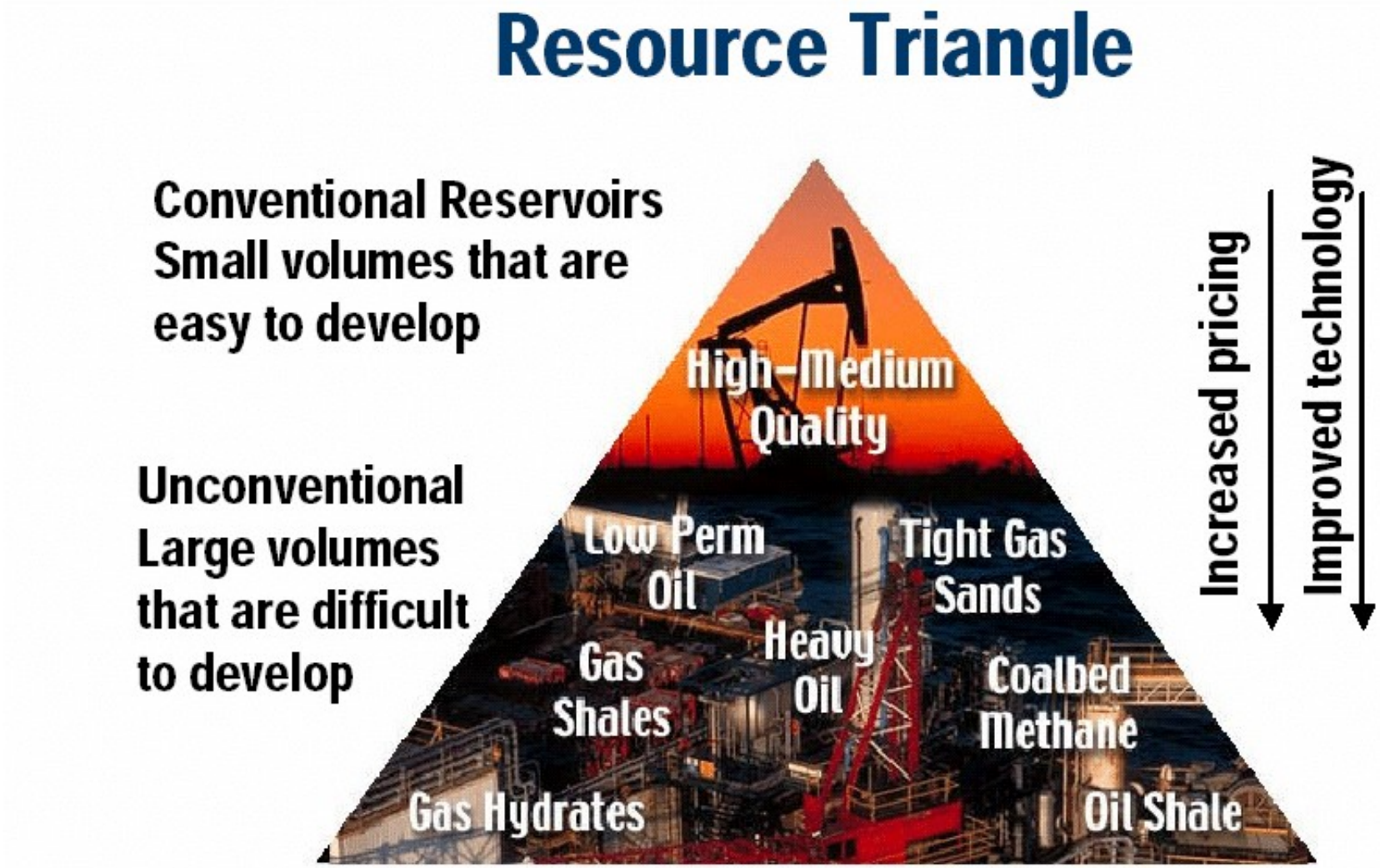
- Growth in Natural Gas Consumption
  - Emphasis on the role of LNG
  - Increasing demand in the power sector
- Reference Source
  - U.S. Energy Information Administration (EIA)
  - Comprehensive outlook on natural gas
  - Short-Term Energy Outlook report

The unconventional fossil fuels

- Unconventional fossil fuels are energy resources which were non-commercial because they were both technical challenging and more expensive in their production.
- **They are mainly four: tar sands, oil shale, shale gas and deep-water oil**, though there are some other potential resources in the future.
- **These unconventional fossil fuels are re-increasing reserves in different parts of the world.**
- They are a expression of the market innovations, when lack of reserves and energy demand drives research and policy to unlock resources previously not considered attractive to exploit



Challenges and benefits from the unconventional resources



A vast number of outlook scenario

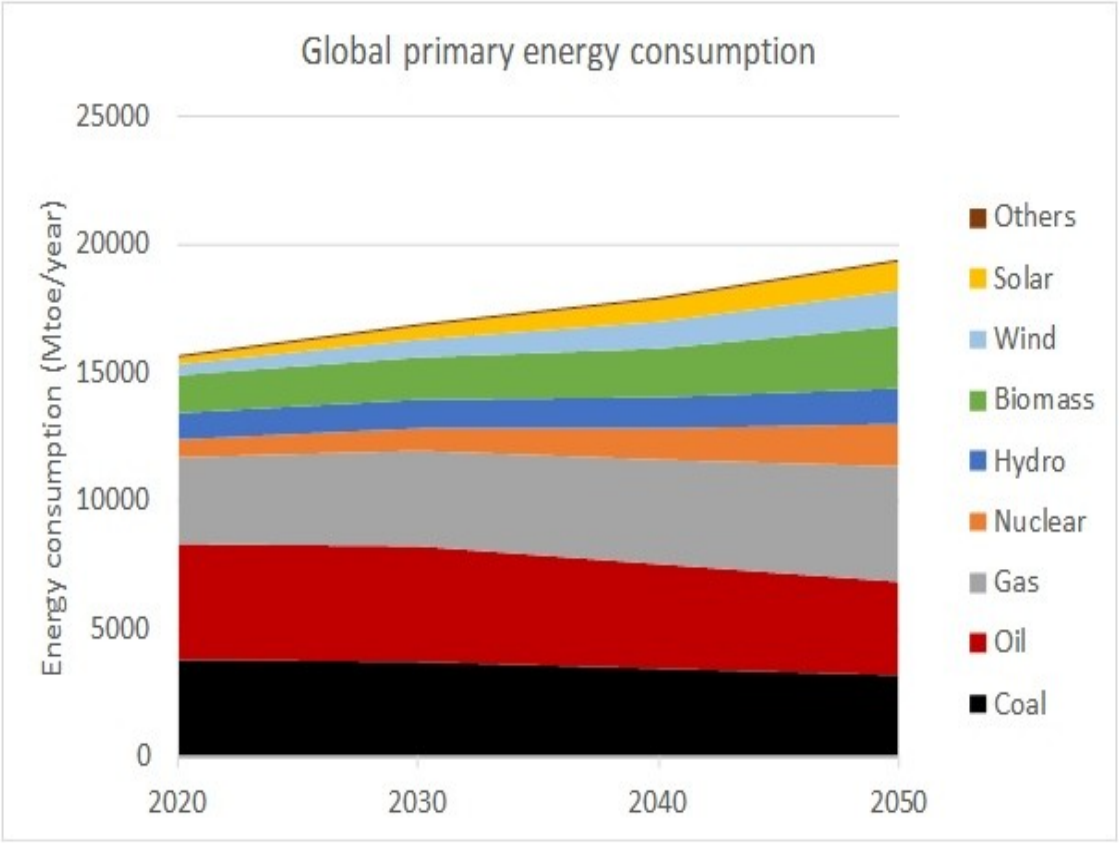
Approaches towards modelling the world energy outlook vary markedly

However, no scenario is meant to be a forecast. Scenarios are projected trends

Do you consider fossil fuels as SUSTAINABLE or UNSUSTAINABLE ?

3 main issues

1. **Fossil fuels are finite**, they take geological times to regenerate, so they are, non-renewable in human terms
2. **Fossil fuels emit pollutants**, which are detrimental to the environment, the more worrying, the carbon emissions, which threat to alter the global climate.
3. **We depend between 80% t0 85% of our energy primary sources on fossil fuels**. It is necessary to set some diversification in such high dependence.

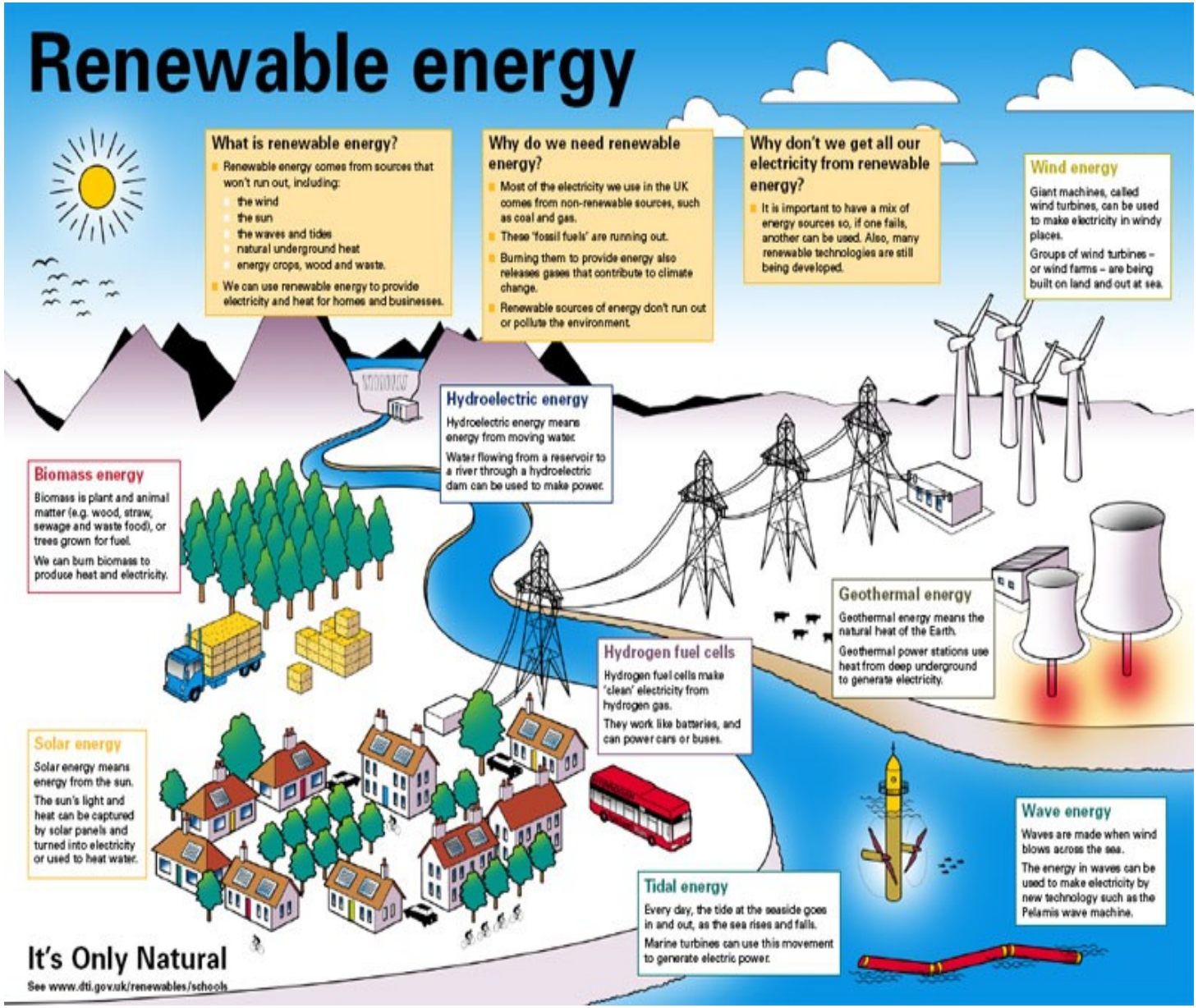


- **The solution is not to stop their use right away**. We cannot do that even if we wanted. Instead, we **should phase them out progressively and in a responsible fashion**.
- The role of fossil fuels in the future stands in providing energy, but **controlling their massive carbon emissions and impacts.**
- At the same time, we should **provide a clear pathway towards renewable energies**, leading to fossil fuels phasing out in some decades.

Energy Trends:
Renewables and Hydrogen

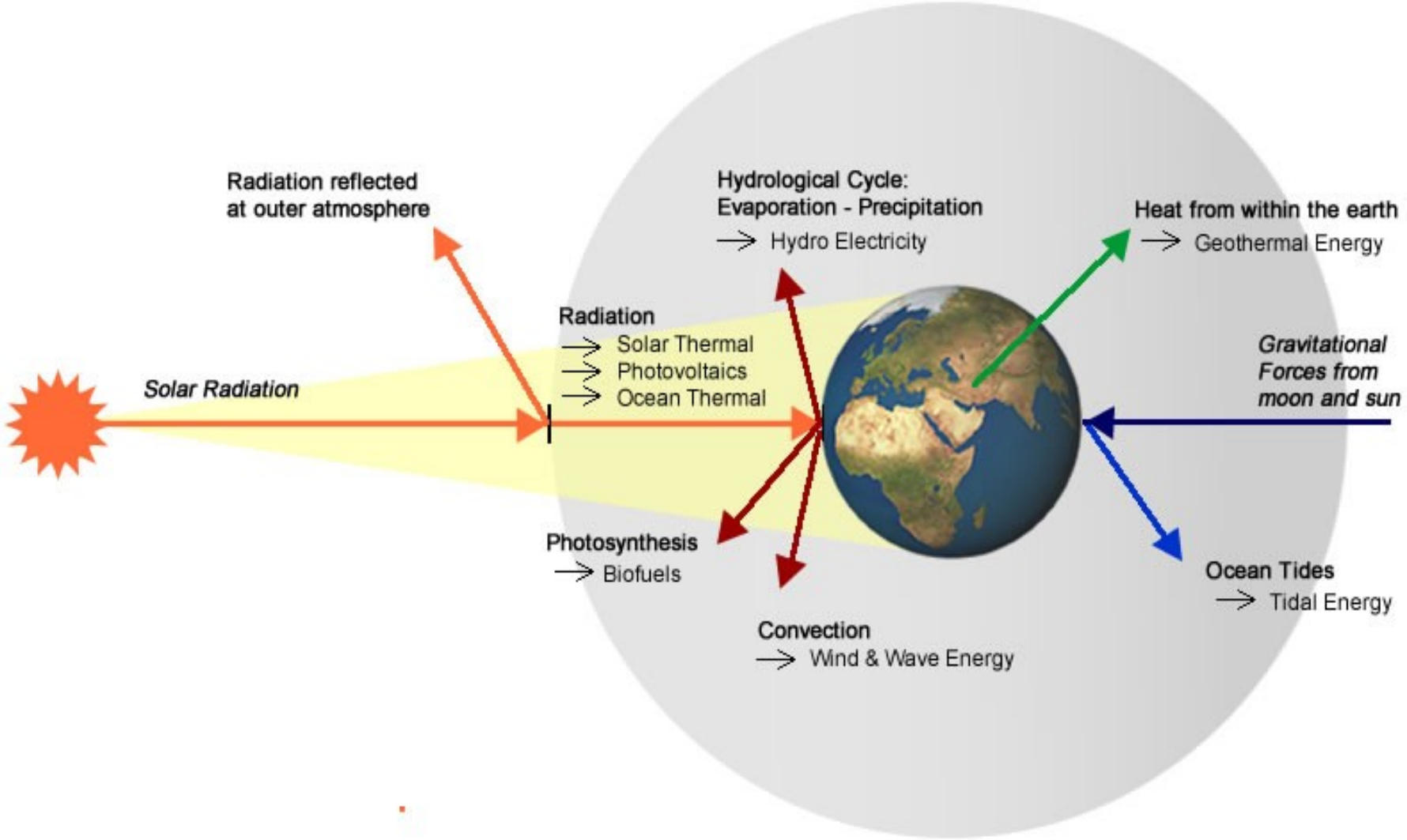
The nature of renewable energies (RE)

- **REs are renewed, no-finite, they can be replenished** during short or human lifetime spans.
- They are not free from environmental impacts.
- However, they do not use energy from prehistoric stocks, but from flows of energy happening around us.
- They release fewer carbon emissions
- Several of them are **intermittent in nature**, i.e., they cannot guarantee a constant supply of energy but only during certain periods of the day

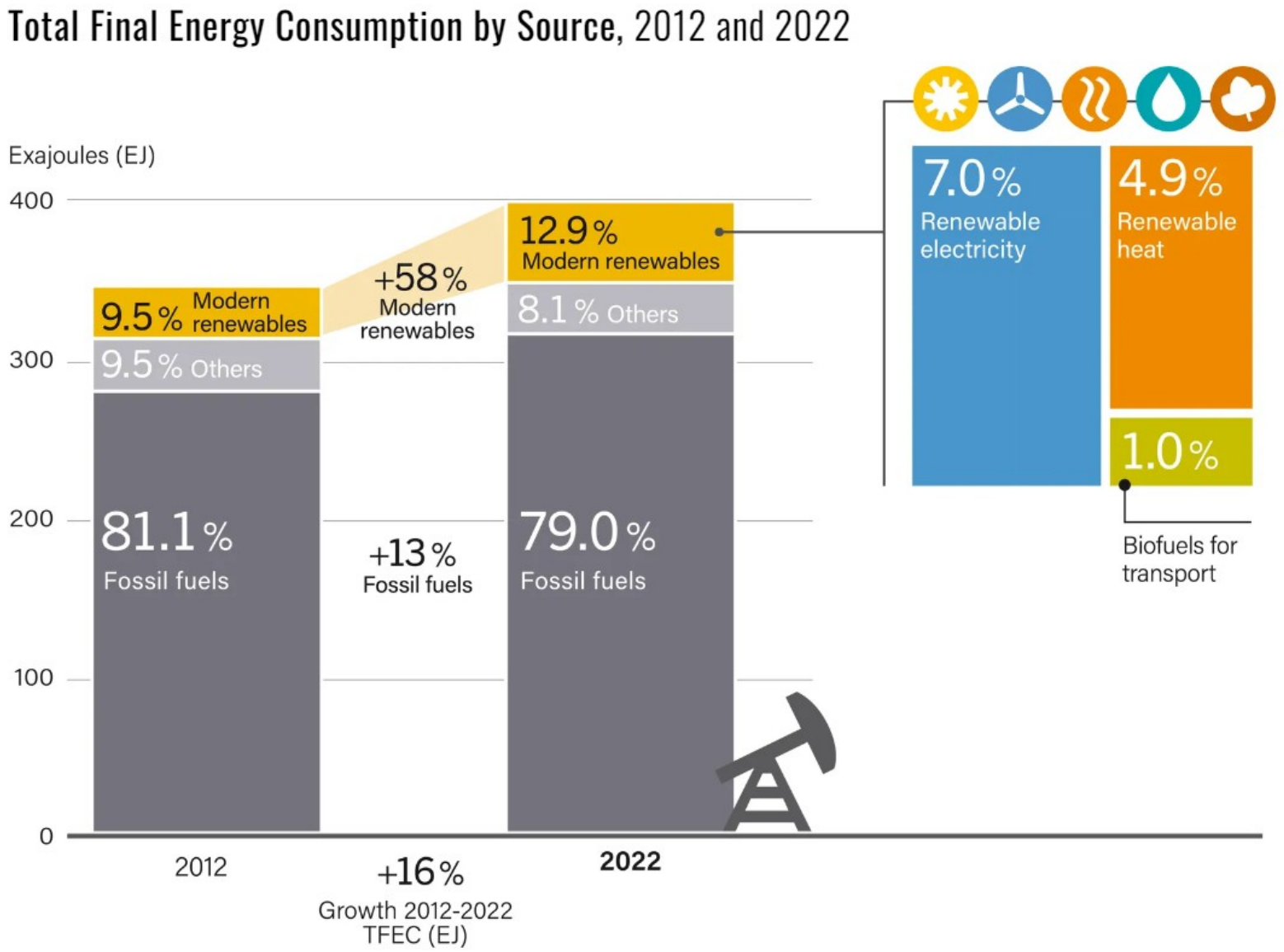


RE Sources

- The flows of energy allowing the operation of REs are the same that feed the Earth's natural processes every day.
- There are **3 mains sources** of renewable energy:
  - **Solar energy** (interacting in different forms in the Earth)
  - **Gravitational forces**: the pull of other celestial forces near the Earth.
  - **Nuclear decay** and frictional forces inside the Earth.
- These sources interact, combine and structure the renewable energy resources we have and

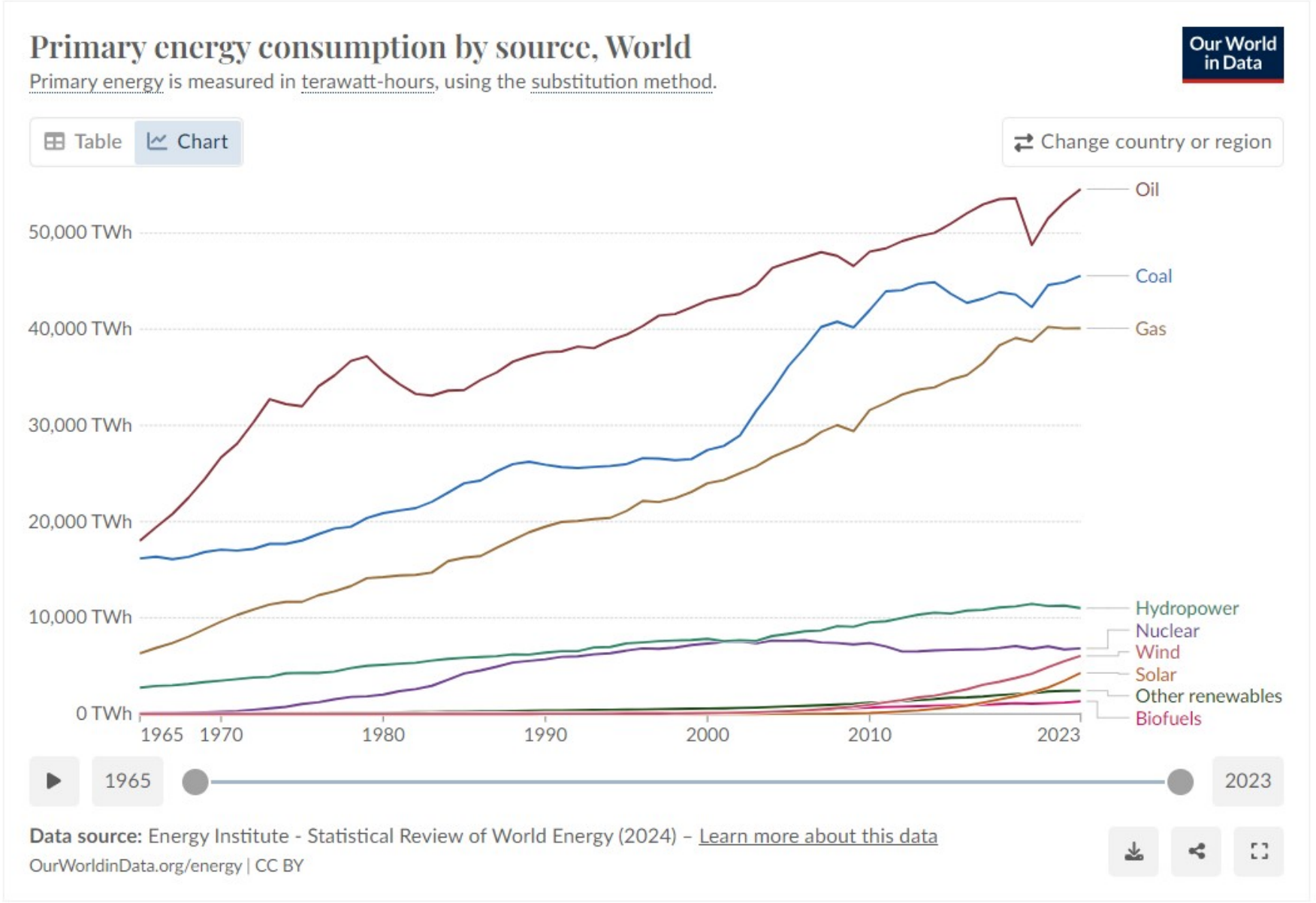


Shares of renewable energies (2022)



- **13% of the energy** consumed globally for heating, power, and transportation was **from renewable sources in 2022**.
- Nearly **60% of this 12% came from modern renewables** (i.e., biomass, geothermal, solar, hydro, wind, and biofuels) and the remainder from traditional biomass (used in residential heating and cooking in developing countries).

Renewable energy into the energy context



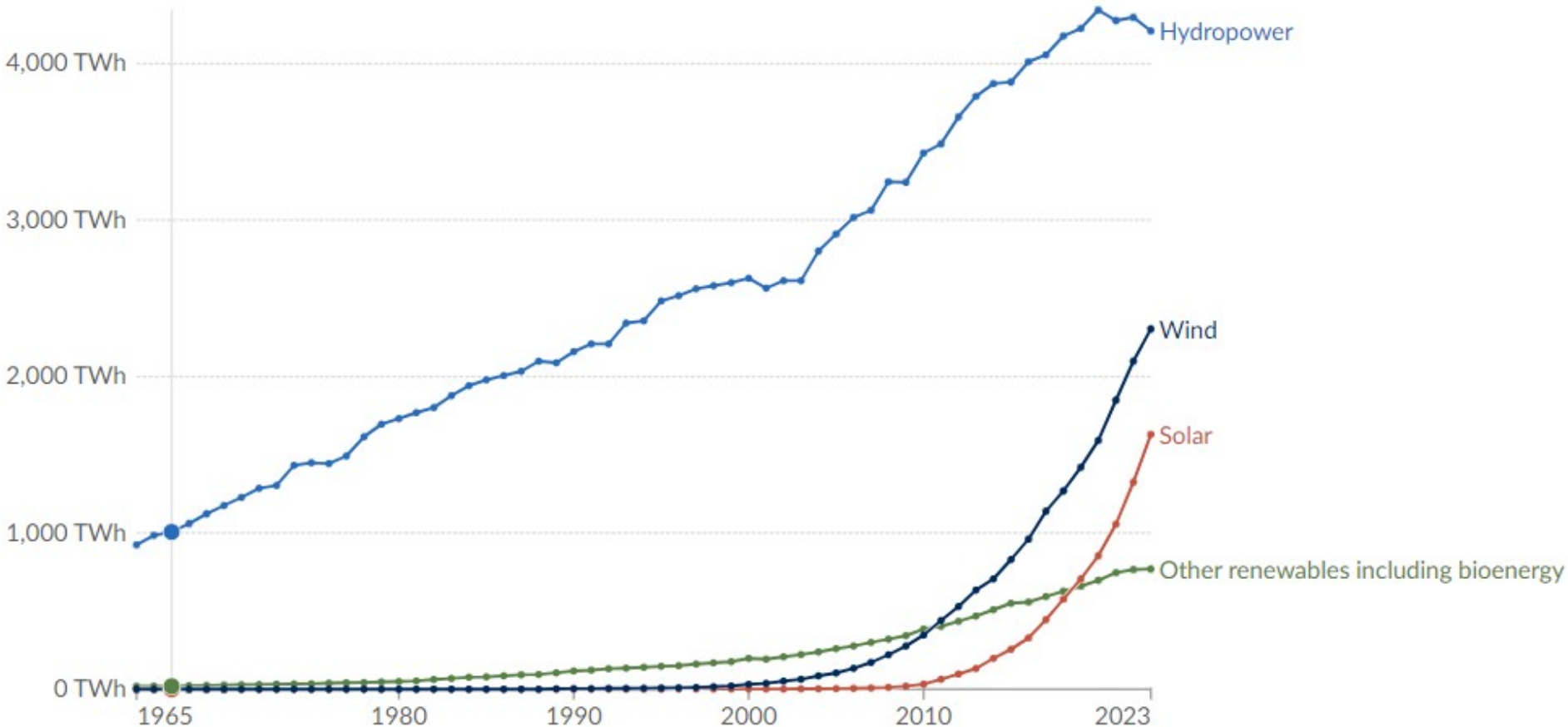
Modern renewable energy generation by source, World

Measured in terawatt-hours.

Our World in Data

Table | Chart

Change country or region



1965 2023

Data source: Ember (2024); Energy Institute - Statistical Review of World Energy (2024) – Learn more about this data

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Renewable energies: final balance

Pros

- Renewable energies are the future: they are mostly **carbon-free or carbon-neutral**, and definitely with minor carbon emissions than mineral fuels.
- They are **sustainable**, they are part of huge stocks and flows of energy which are **constantly regenerated**. They **do not harm nature**, altering it seriously.
- They are **growing cheaper** and in many cases, their **operation is close to free** because the energy flows from the environment are free.
- They have a **huge potential**, they are ubiquitous and have global reach.
- They **create jobs and new industrial-economic activities**

Cons

- There is still a **long way to make RE commercially attainable**. Also R&D should work a lot on the technological feasibility and potential of many of them.
- They are **not impact-free**. RE have different impacts, some of them difficult to accept, but we can work them out.
- **Installation/upfront costs could be very high** in some of them.
- Using RE is going to alter definitely our energy systems and power networks, needing a **change on the model of huge producer**, multiple consumers to multiple small consumer/producers (prosumers).
- Also, we would need to **work more on smart networks** capable of managing the exchanges of power among multiple players

Hydropower energy

- Hydropower energy is **one of the most used renewable energies.**
- It was greatly **developed in the Industrial Revolution** and allowed the electrification processes in many parts of the world.
- **It uses the water potential and flow energy to produce electricity.**
- 3 types of Hydropower installations
  - Impoundment hydropower
  - Diversion or run-of-the-river
  - Pumped storage hydropower

Hydropower

Advantages

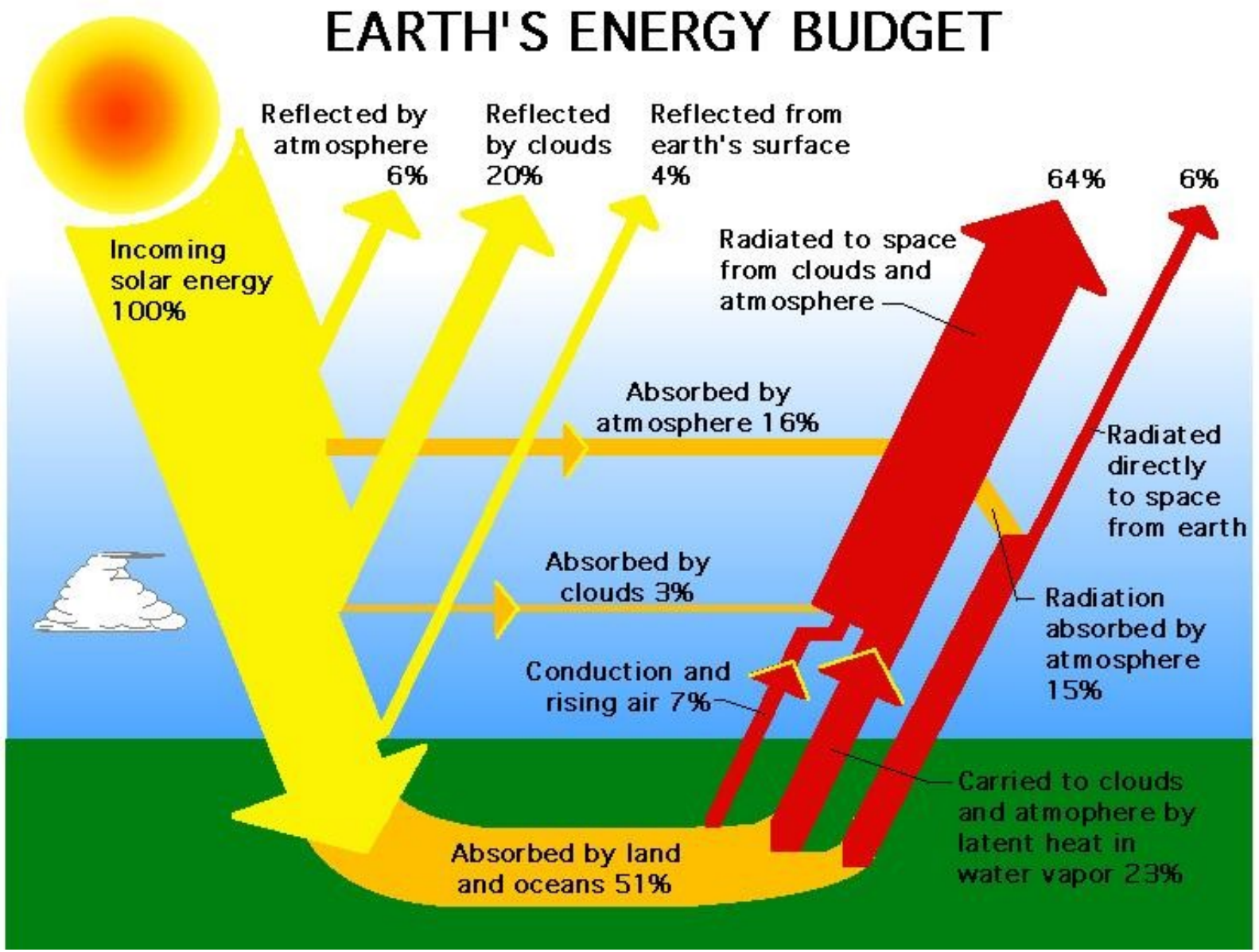
- It is a **well known source of energy** with a mature developed technology.
- It is a **continuous source of energy**, reliable in terms of time and easily complemented by other sources if needed.
- Besides the construction stage, there are no carbon emissions.
- It is **available when needed**, you just need to open the water flow to the turbines and direct the power where needed.
- The water impoundments or reservoirs created behind the dams could be used for fishing, recreational, swimming or other purposes.
- It is also useful as a mean for flow control and water supply.

Disadvantages

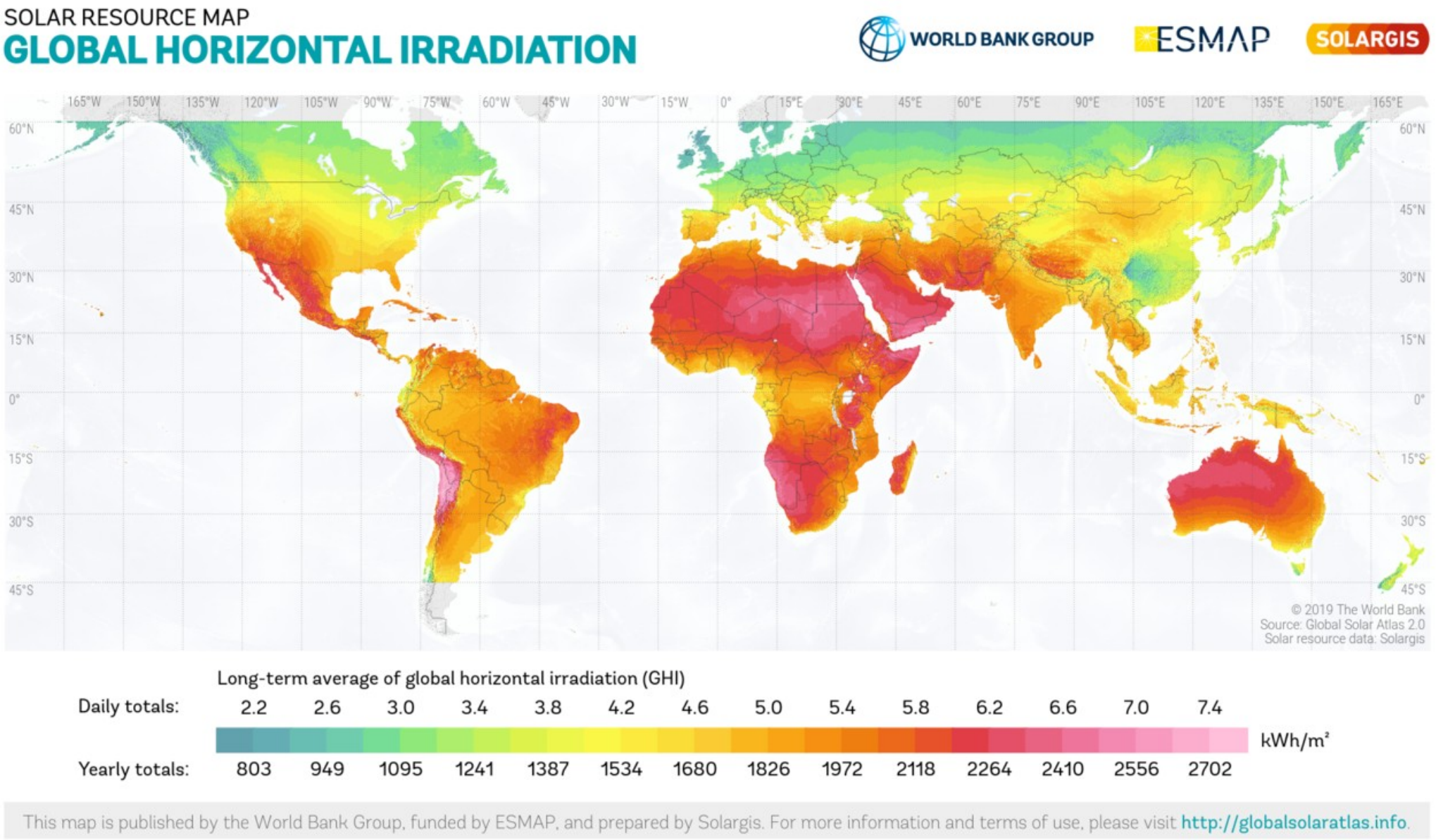
- There is **not too much potential left**, the best hydropower potential places have already been used.
- **Dams disturb the normal course of rivers** and associated habitats.
- **Fishes / water species and habitats are disturbed by the dams as they are not free migrate as before**.
- The use of land is altered by the water impoundment, which could have agricultural, cultural and other values.
- **Hydropower is seriously affected by droughts.**
- Sediments and minerals dragged downstream are interrupted, **impacting soils fertility**.

Solar Energy Potential

- The Sun is a star **radiating energy all over the Solar system**
- It reaches the Earth atmosphere, radiating 1354 W/m2 or 429 BTU/ft2 hr)
- Depending on weather conditions, season and hour, it **reaches the Earth surface between 0 and 1050 W/m2**



Challenges & Opportunities in Middle East



Types of solar energy technologies

Solar photovoltaic systems

Simple photovoltaic systems

Concentrated photovoltaic systems

Solar thermal electric systems

Solar thermal

Concentrated solar power

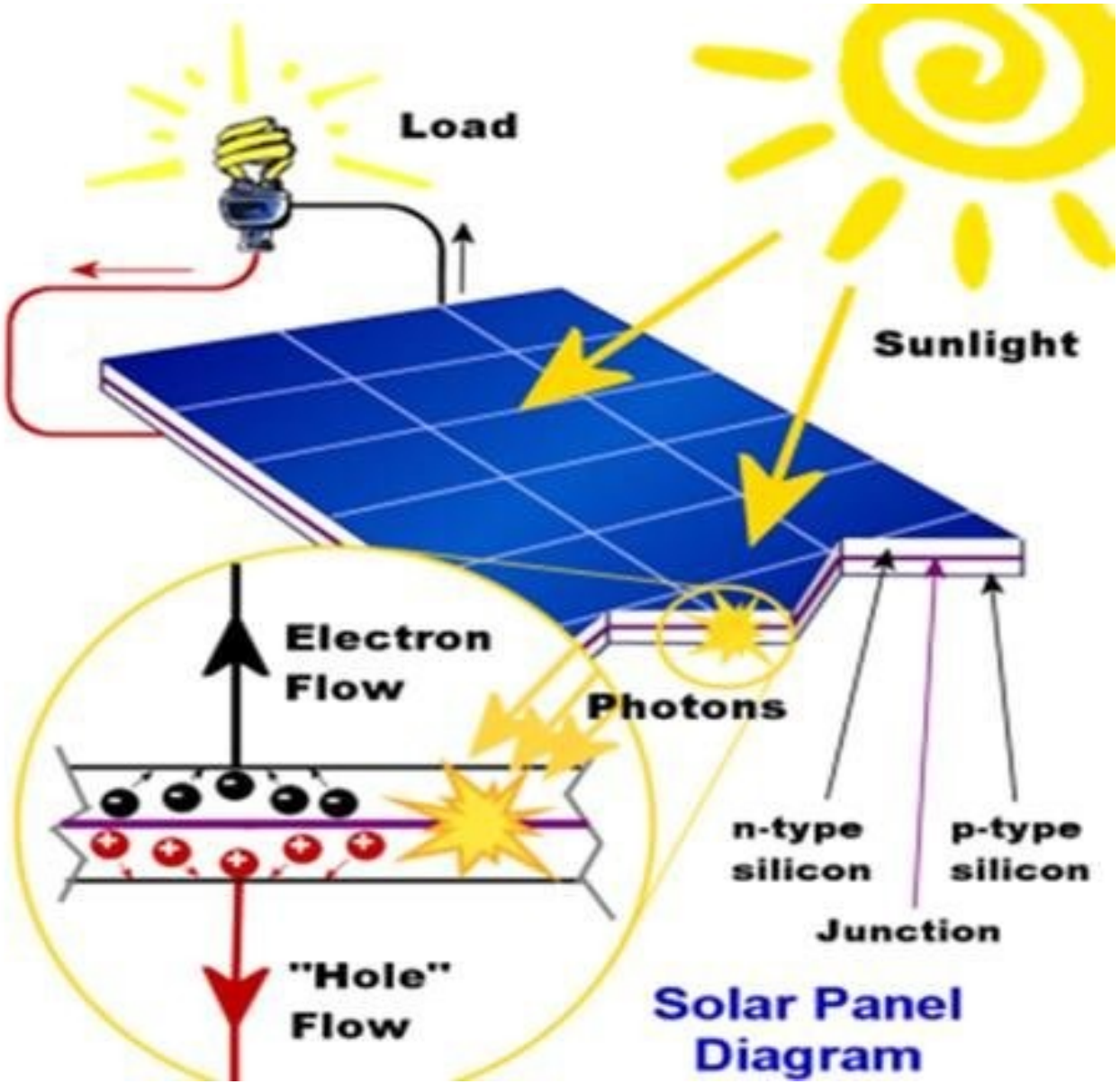
Photovoltaic systems make use of the **photoelectric effect**, the **radiation of solar energy in a surface to generate electricity**

Thermal systems try the **collect the Sun heat energy on the surface to heat fluids** and make **use of such energy as heat or power**

Solar photovoltaic systems (PV)

How do they work?

- Photovoltaic (PV) systems are based on the **transformation of infrared light into electric energy** (photoelectric effect).
- Incoming light is converted into electrons (-) and holes (+) by absorption of photons. Usually one photon makes the electron – hole pair.
- **PV systems must be made of materials which make easy the flow of electrons into one direction.**
- Complementary, PV systems should have holes flow in the opposite direction.
- **PY systems are made of semiconductor materials**



Solar photovoltaic systems

Simple or conventional PV

- **Simple PV systems are static panels** of PV.
- They are the classical panels **used on rooftops of houses and commercial premises.**
- They are also in some industrial applications and off-the-grid installations.
- **Their popularity comes from their versatility to install, operate and maintain**

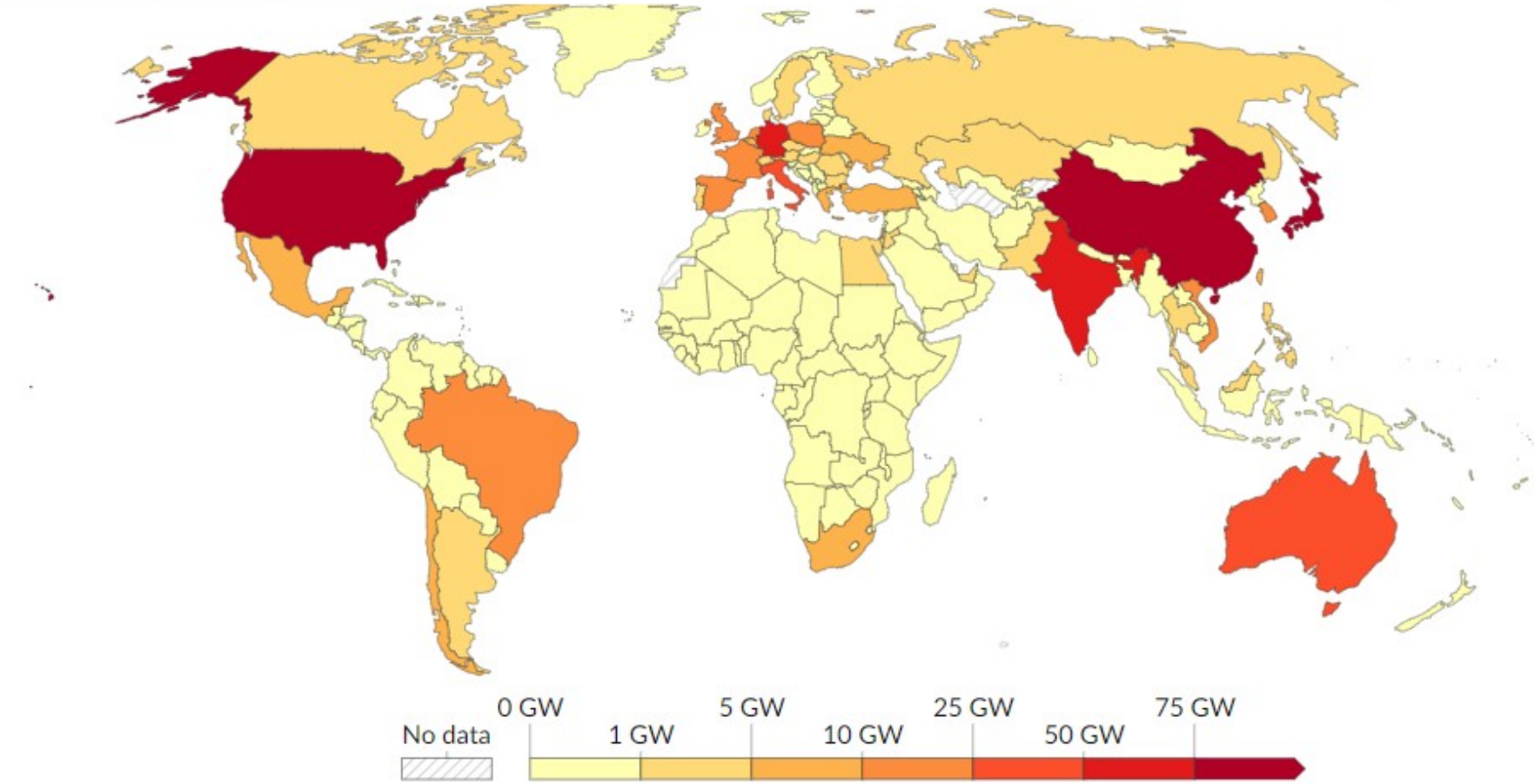
Installed solar energy capacity, 2022

Cumulative installed solar capacity, measured in gigawatts (GW).

Our World in Data

Table | Map | Chart

World



2000 — 2022

Data source: International Renewable Energy Agency (2023) – Learn more about this data

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Solar photovoltaic systems

Concentrated PV systems

- They **use the same photoelectric effect as with conventional PV systems.**
- However, unlike conventional PV, **concentrated PV (CPV) make use of concave lenses to concentrate the solar light.**
- **The lenses concentrate such light onto a small, highly efficient multi-junction (MJ) solar cells.**
- Often they use a solar tracker and cooling system to enhance the efficiency.
- CPV is starting its way to be commercially competitive, for instance in the US, China, Europe.
- **It is one of the most efficient solar technologies, and has a bright future**

Solar Thermal Electric Systems

Solar Thermal

- Solar Domestic Hot Water (SDHW): Flat Panels.
- SDHW: Thermo syphon
- SDHW: Evacuated Tube Collectors
- Solar air panels
- Trombe Wall
- Solar Chimney

Solar thermal systems use the thermal energy of the Sun to hot other fluids or generate electricity.

Concentrated Solar Thermal

They work the same as the normal solar thermal systems, but make us of configurations to **concentrate the sun beams and transfer the heat to the fluid exchanger.**

Solar technologies: Pros and cons

Advantages

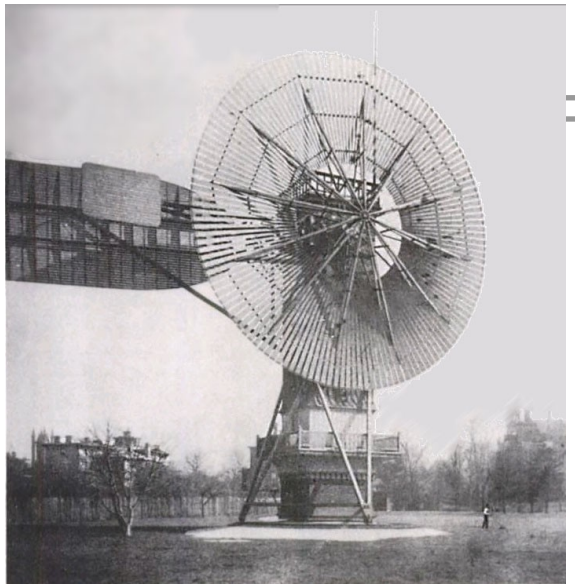
- **Renewable energy,** with very few carbon emissions during operation.
- Could help to **reduce the electricity bills** and even **sell power to the grid.**
- **Adaptable and versatile for small installations and off-the-grid / isolated areas**.
- **Low maintenance costs**, at least in the most mature and domestic technologies.
- Continuous technological development, reducing costs

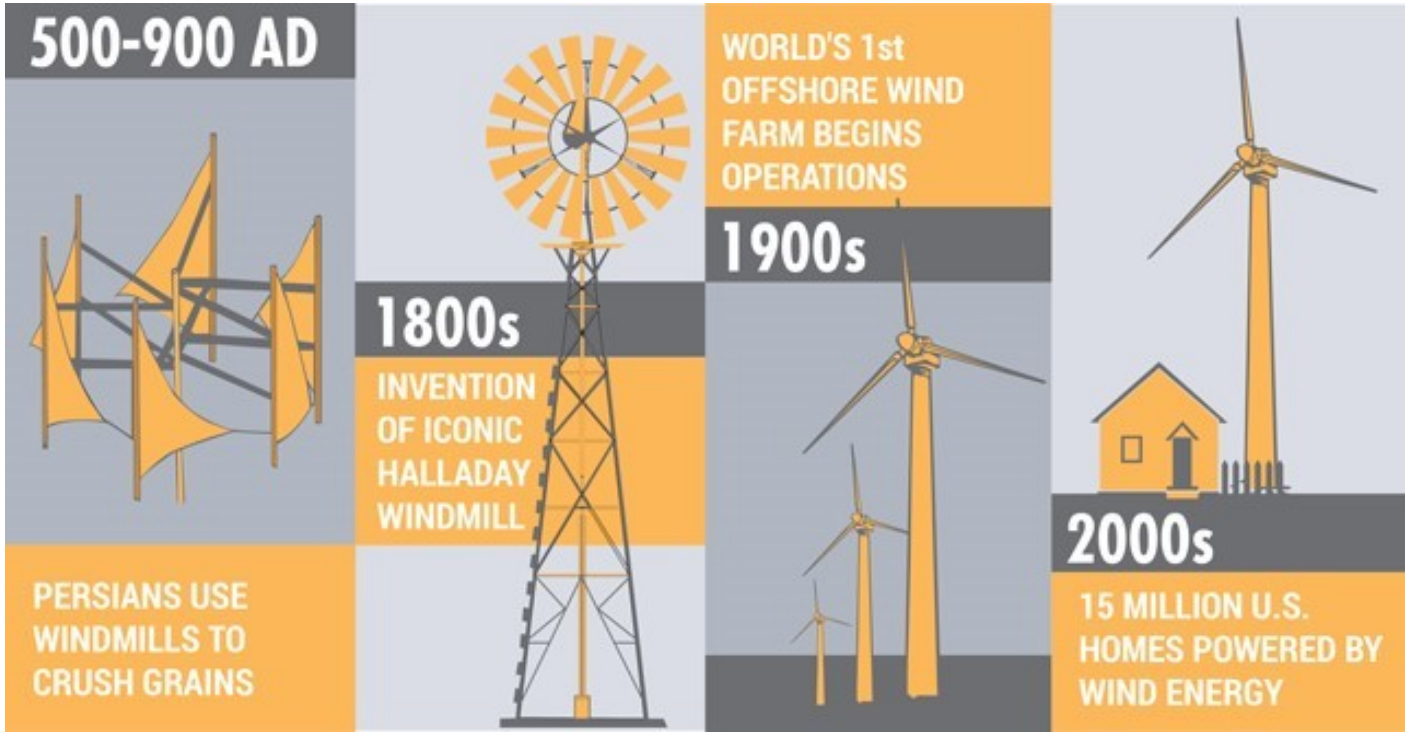
Disadvantages

- **Procurement and installation costs could still be high**.
- It **depends highly on favorable weather conditions and season**.
- There are still **problems on the energy storage side.**
- Could **use a considerable space** (the industrial configurations)
- **Associated with other types of pollution, on the demand of special manufacturing materials for PV.**

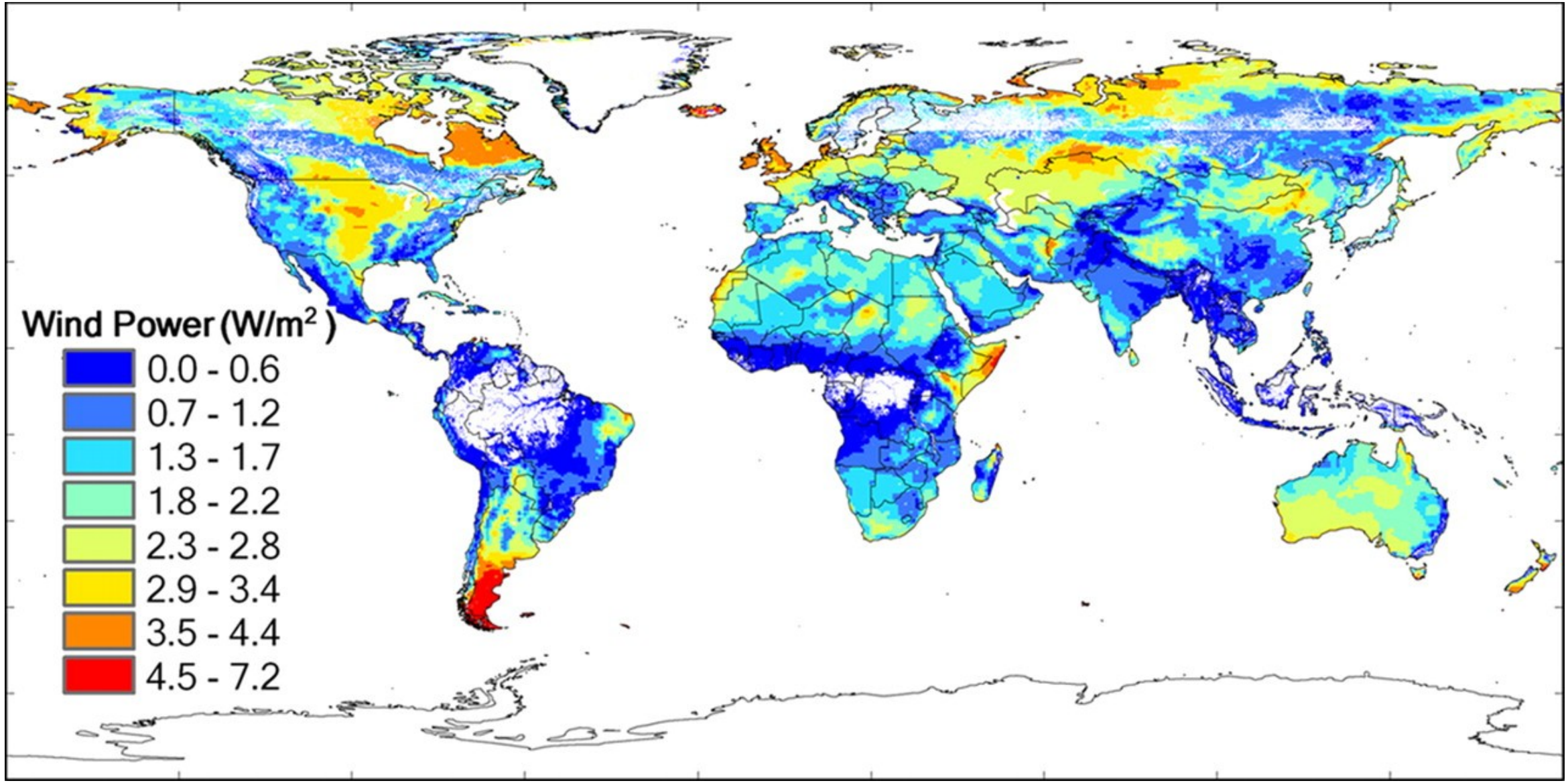
Wind power

- Wind energy is **one of the main renewable energies and used since ancient times.**
- Wind was used as far as to **power sail ships and windmills for farmers in Europe in past centuries.**
- Wind comes from the uneven heating of the land and sea surfaces (i.e. wind energy stems from solar energy).
- **Wind energy is one of the main potential renewable energies**; by the use of wind turbines and mills, it harvests free energy.
- **The total amount of economically extractable power available from the wind is considerably more than present human power use from all sources** (source https://claverton-energy.com/how-much-wind-energy-is-there-brian-hurley-wind-site-evaluation-ltd.html)

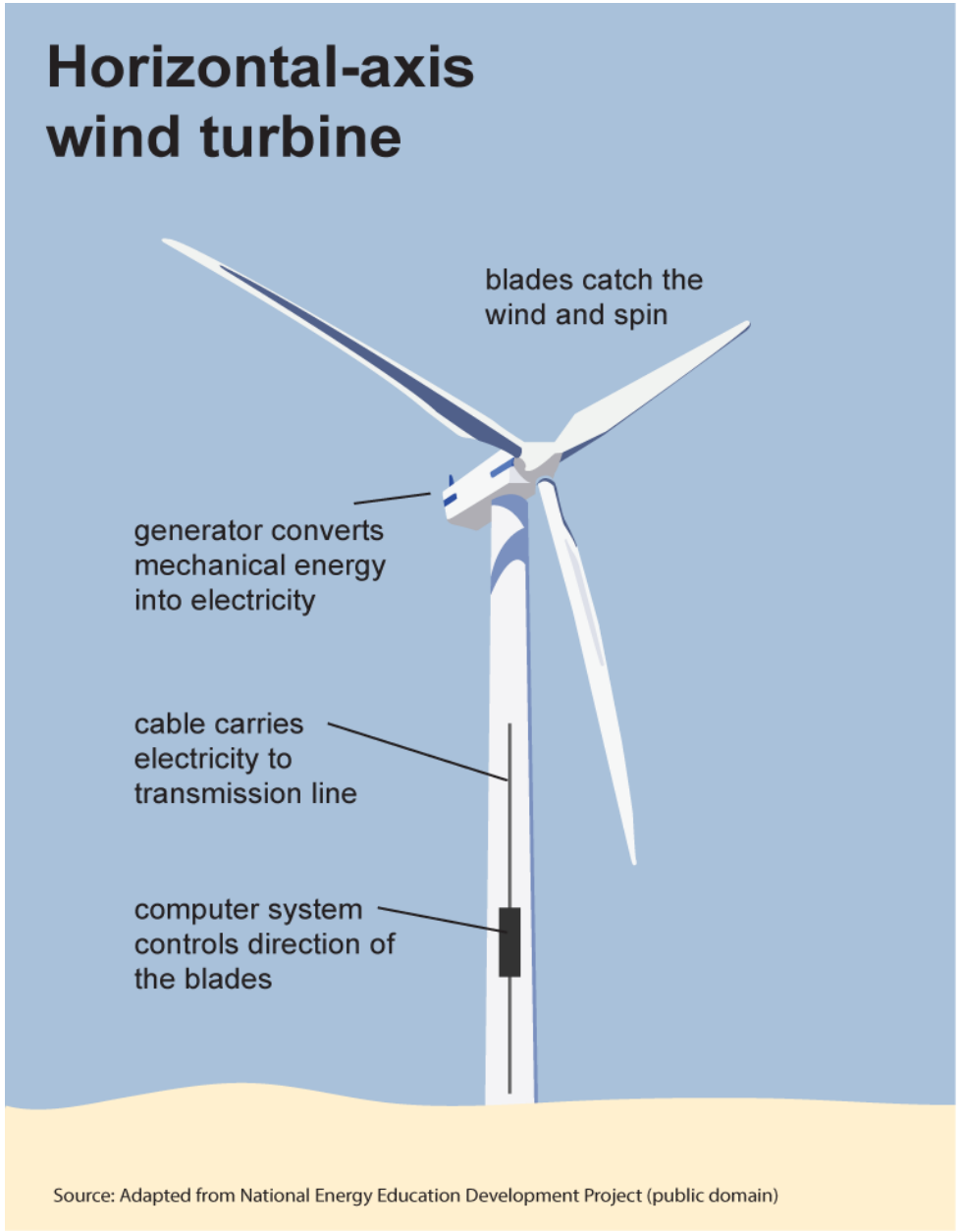




Wind power potential



Wind turbines and wind farms



- **Wind turbines are used to harness wind mechanical power by rotating an electric generator.**
- There are 2 main types of wind turbines: a) horizontal axis b) vertical axis. Horizontal are the most used.
- Almost all large wind turbines have the same design — a horizontal axis wind turbine having an upwind rotor with 3 blades, attached to a nacelle on top of a tall tubular tower
- Usually **wind turbines are installed in large clusters, called wind farms, either onshore and offshore.**
- **Wind farms are all connected to gather the generated electricity and dispatch to the power transmission network.**
- Wind potential depends on the location and increases with altitude, i.e. **wind speed is higher at higher altitudes and locations.**
- A large wind farm may consist of several hundred individual wind turbines distributed over an extended area

Wind power on Land & at Sea

Onshore

- **The largest wind farms are located onshore**.
- They are usually located on coastal areas, top of hills, plains and even agricultural fields.
- An example is the **Gansu wind farm in China, the largest in the world with 10.45 GW and expansion is ongoing to reach 20 GW.**
- There are many large wind farms in the US.

Offshore

- Even though it is **more difficult and expensive**, there are large offshore wind farms.
- Offshore wind farms use unlock the large potential of marine areas, where **wind runs free for kilometers at faster speeds**.
- In 2012, **1,662 turbines at 55 offshore wind farms in 10 European countries produced 18 TWh, enough to power almost five million households.**

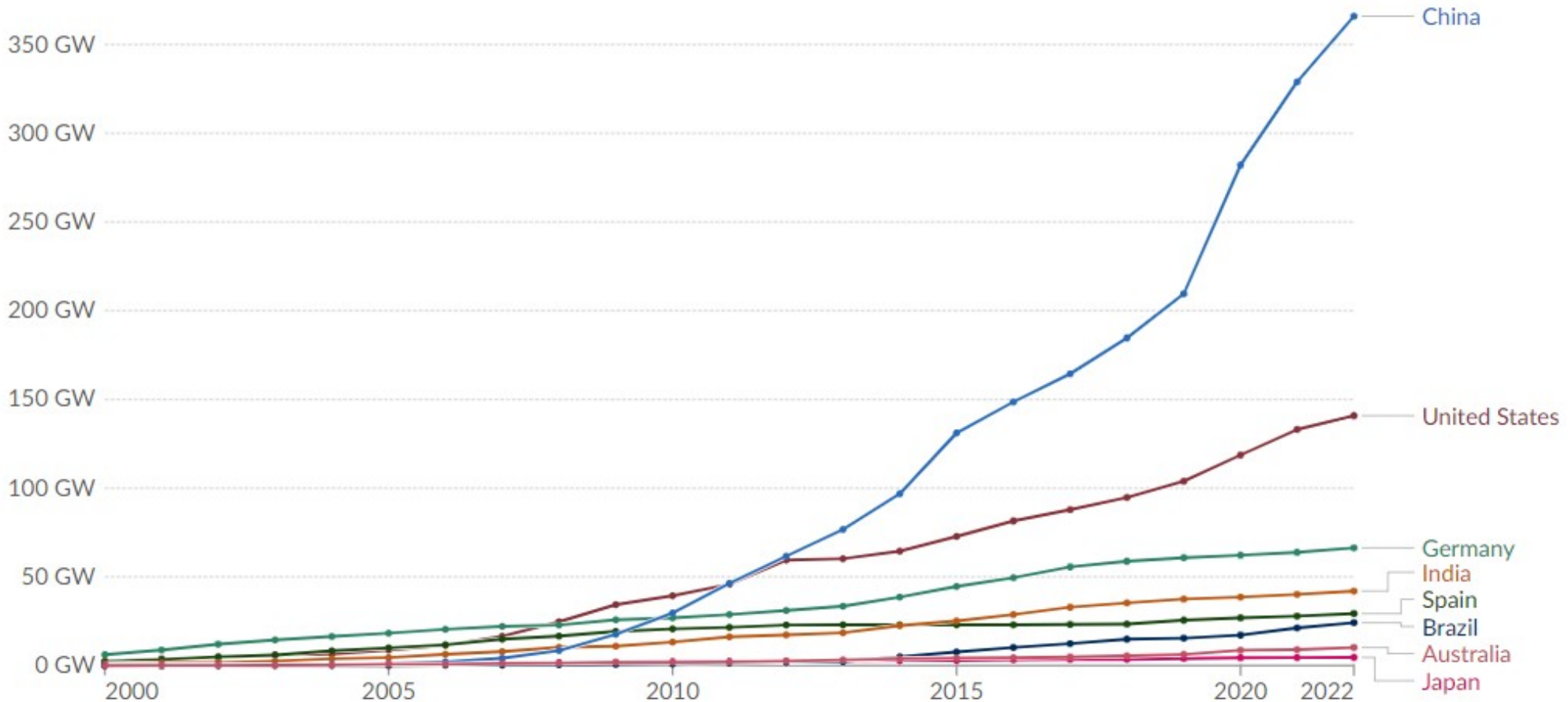
Installed wind energy capacity

Cumulative installed wind energy capacity including both onshore and offshore wind sources, measured in gigawatts (GW).

Our World in Data

Table | Map | Chart

Edit countries and regions



2000 2022

Data source: International Renewable Energy Agency (2023) – Learn more about this data

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Wind power: Pros and cons

Advantages

- **A renewable and sustainable source of energy**, with no carbon emissions during operation.
- Depending on the potential, location, installation, **wind power is free and with a large potential**.
- Wind turbines could be installed in ranches, farmlands and **without major disturbances on the land activities.**
- Small wind turbines (vertical axis) can even be installed next to roads, or urban settings to provide small amounts of power.
- **Wind power creates jobs.**

Disadvantages

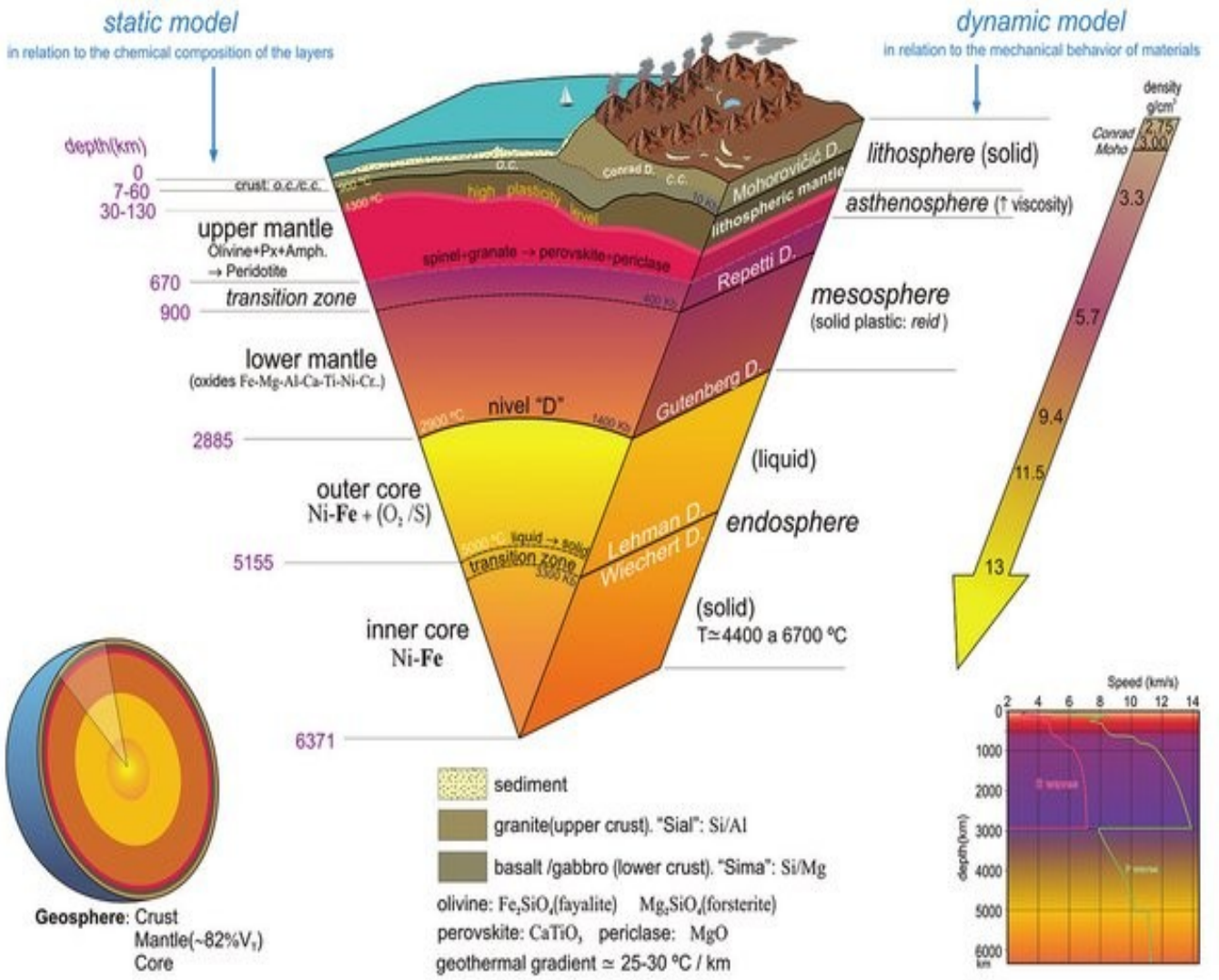
- It is **intermittent in nature, it cannot provide power all the time**, at all hours and seasons.
- One should know the **best locations** to install the turbines and get the most of power (something difficult).
- Noise and aesthetic issues: Not many people like the look of wind farms near their houses or towns. **Wind turbines may be heard hundreds of meters away from their location.**
- **Threat to wildlife**: many windmills have been reported to kill birds, bats, etc.
- **Cost of land:** the land used for wind farms could get more profitable uses.

SOLAR AND WIND ENERGY GROWTH

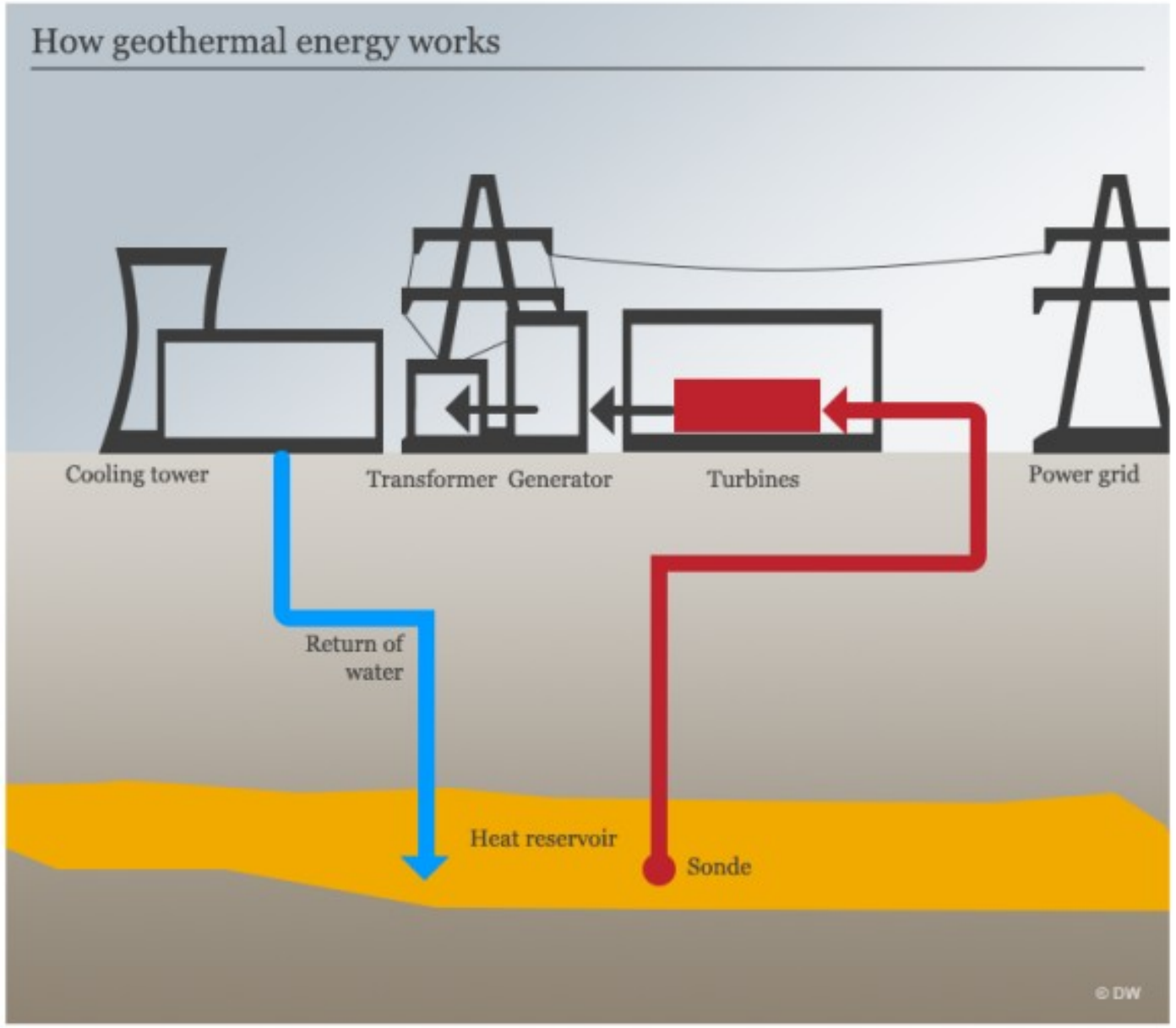
- Solar and Wind Energy Growth in 2024
  - Expected to dominate global renewable energy expansion
  - Will generate more electricity than hydropower
- Future Projections
  - On track to surpass coal as the largest sources of electricity generation by 2025
- Supportive Factors
  - Declining generation costs for solar PV and wind energy
  - Increased competitiveness compared to fossil and non-fossil fuel alternatives

Geothermal Energy

- Geothermal energy is **thermal energy generated and stored below the Earth's crust.**
- It is originated 5-10% from the old processes when Earth was created thousand of million of years ago.
- The rest comes from radioactive decay of nuclear elements such as uranium and plutonium.
- **Earth is composed of several layers**, but in general we have a) the **core**, b) the **mantle**, c) the **crust**.
- **The Earth irradiates heat from the core, which is around 5500 ºC.**
- The heat reaches the mantle.
- **Constant geological processes release part of this thermal energy in volcanic and plate-boundaries areas.**
- **Heat flows through the crust of the earth at a rate of 0.65W/m2 under the continents and 0.101W/m2 through the ocean floor**. The resulting thermal temperature gradients range from 25o and 30o / km.



Geothermal Energy



- **Geothermal systems need a hot formation source**.
- From there we can get fluids or **pump down fluids through wells to the geological formations to extract the heat**.
- **The fluids sweep across the hot formations and return to surface to the turbines, which are rotated.**
- **The turbines make work the generators and we have electricity.**
- **Finally, the spent fluid is cool down and**

Geothermal: Pros and Cons

Advantages

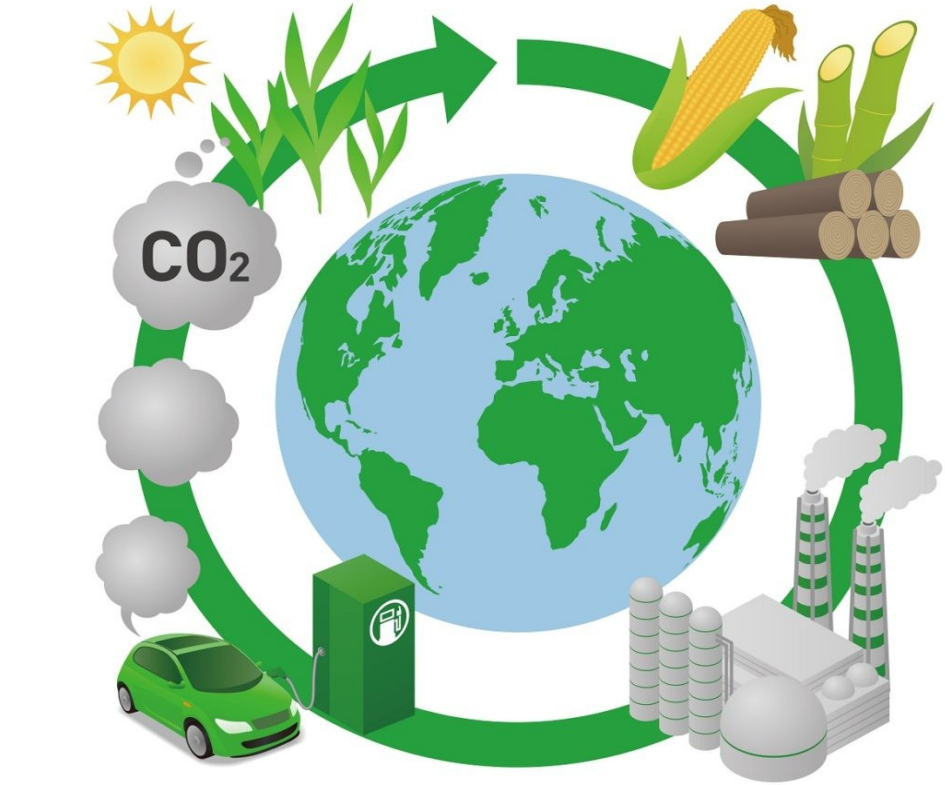
- Almost **no combustion, so environmentally friendly.**
- **Efficient** (300- 500% compared to 90% of the best furnaces)
- **Suitable for the smallest of houses to the largest commercial spaces**.
- It is **not fluctuating by the weather, season, solar activity.**
- **Most facilities underground, so minimal landscape disturbance.**
- It can make use of petroleum technology and abandoned oil and gas wells.
- Provides either base load or peak power energy output.
- Technology improvement continues (for instance in fracking underground formations)
- **It is basically inexhaustible**

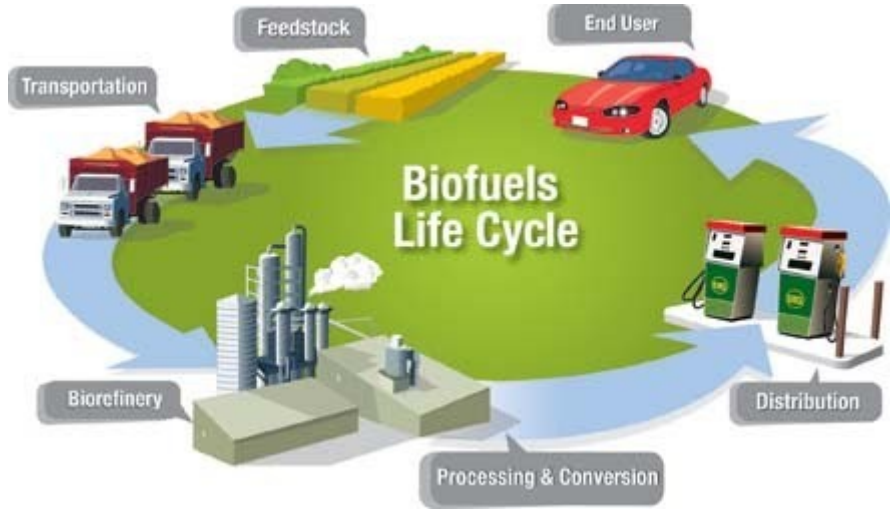
Disadvantages

- **High upfront costs with implementing geothermal energy.** ($10,000-$20,000)
- **More suitable for new home** builds as retrofitting involves large scale excavation.
- **Requires large quantities of water** if we plan to pump down water in the wells.
- Discharge into the Earth could include sulfur dioxide and silica (well pumps).
- **Electricity is still needed to operate heat pumps.**
- **Damage to underground loops (tree roots, rodents, etc.)** can be difficult and costly to repair.
- **For hydrothermal systems, not many places with available potential**

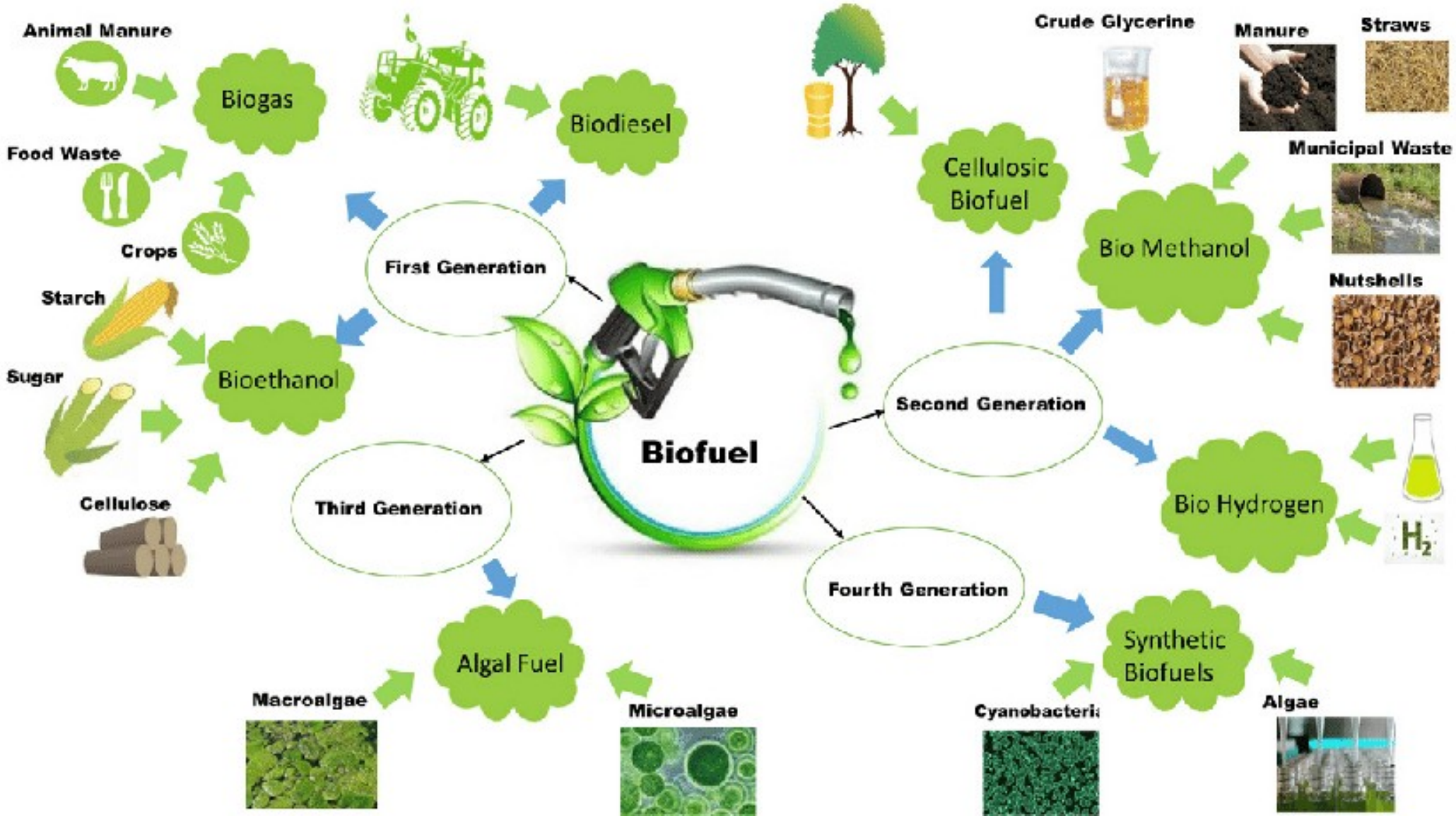
Biofuels

- **Biofuels are fuels made of contemporary processes from biomass** (unlike fossil fuels).
- The term **biofuel is usually reserved for liquid or gaseous substances** used as fuel for transportation.
- Biofuels **can be used as pure fuels in engines**, but they are mostly mixed with hydrocarbon fuels.
- Biofuels **feed stocks include plants and different types of wastes**. They help with carbon fixation and carbon sequestering.
- **The most used biofuels are bioethanol and biodiesel.**

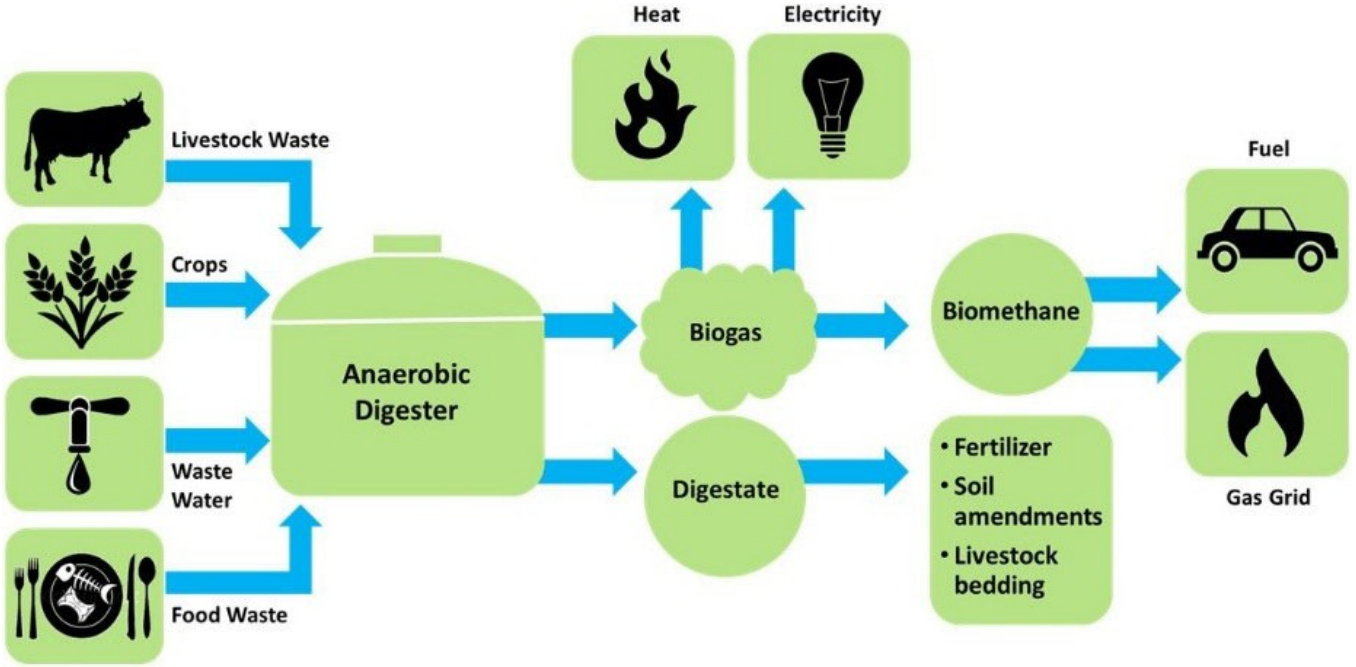


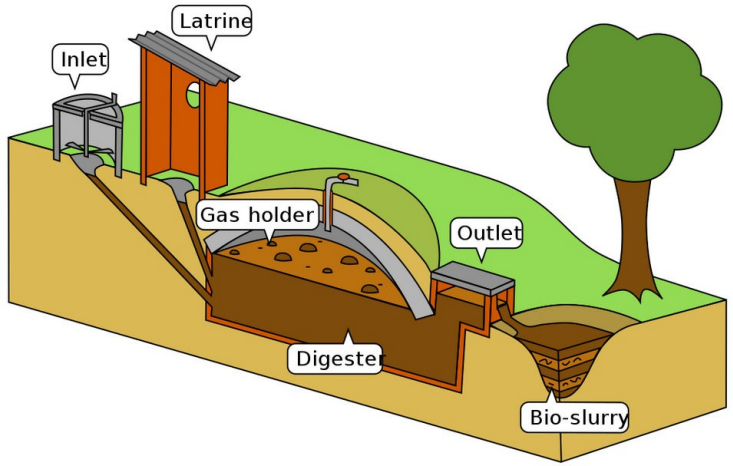


Different types of biofuels



Biogas





- It is **methane produced by the process of anaerobic digestion of organic material by anaerobes**.
- Produced either **from biodegradable waste materials** or by the use of energy crops fed into anaerobic digesters to supplement gas yields.
- The solid byproduct can be used as fertilizer or biofuel.
- Farmers may produce it from processing manure of their cattle.
- Another example of biogas is **landfill gas**, methane produced from natural anaerobic digestion in landfills. If released, it is a potent GHG

Biofuels: Pros and cons

Advantages

- **Biofuels are environmentally friendly, more efficient and cleaner than fossil fuels**.
- **Biofuels are cheap**, since they can be manufactured from local materials, byproducts, refuses, etc.
- **They are versatile**, they can be used alone or in mixtures with mineral fuels. They can even be used as additives for other fuels
- **They are renewable**, the feed stocks are varied selections of **biomass which are produced naturally.**
- **They are carbon neutral**, do not emit carbon stored from past geological eras, and capture carbon when feed stocks are grown.

Disadvantages

- There is a lively debate about the **use of land and resources for biofuels production instead of food production.**
- If we use more land for biofuels production, we can **predate more habitats and ecosystems**.
- Biofuels capture CO2, but they may **release NO2**, another potent GHG, during the burning of materials for production.
- When biofuels are used in some common engines, the **engines need to be adapted or modified.**
- They are not very widely known, and they **need more R&D to make commercial** processes of experimental feedstocks.

What are the three gases of GHG?

Carbon Footprints & GHG gases

A carbon footprint stands for a certain amount of gaseous emissions that are relevant to climate change and associated with human production or consumption activities and most of time it is only CO2

GHG includes the greenhouse gases of carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), together with families of gases including hydrofluoric carbons (HFCs) and perfluoric carbons(PFCs)

How do you measure carbon footprint:

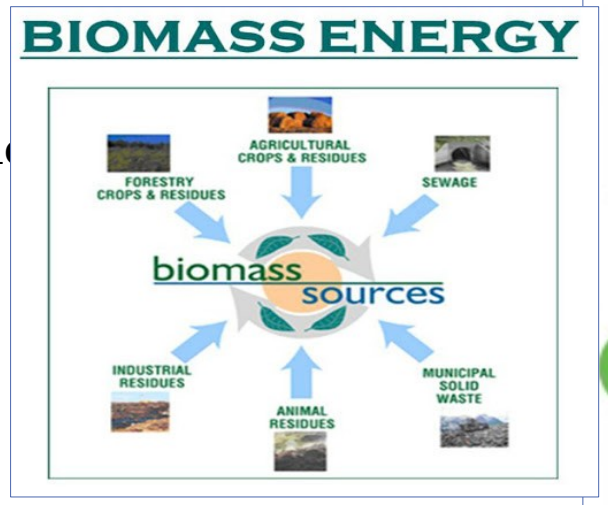
“pressure indicator” express the amount of carbon emissions in tones

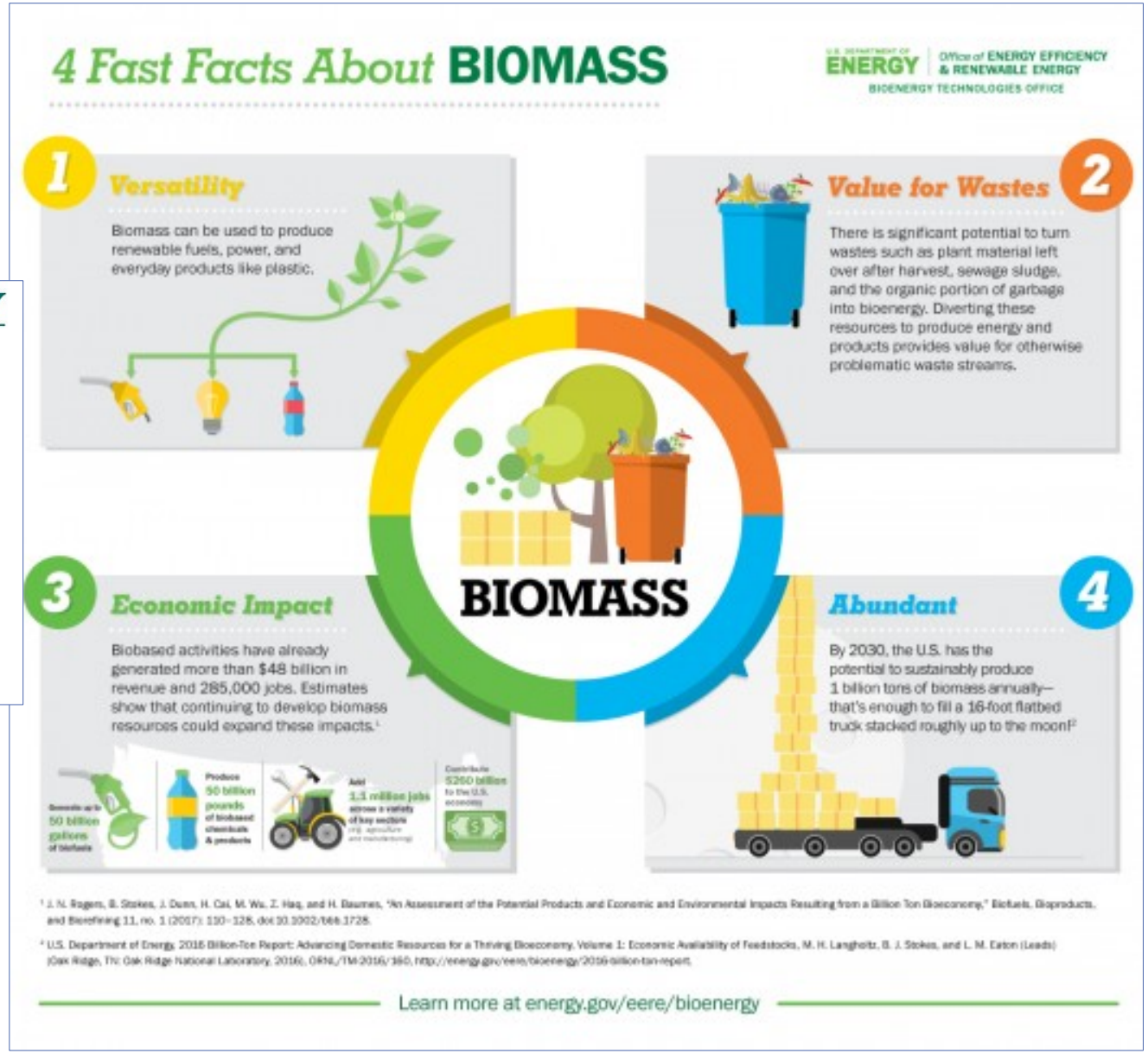
impact indicator expressed in CO2 equivalents (t CO2–eq.) as a measure of global warming potential

land appropriation indicator area-based unit (amount of land needed to sequester CO2)

Biomass

- **Biomass is made up of all living plant matter as well as organic wastes.**
- Trees, grasses, dump, dung, etc.
- Ancient biomass formed the fossil fuels, but present biomass is the one found in the biosphere now, interacting with the natural cycles and ecosystems.
- Biomass was the first source of energy used by humans in History.
- Many forests were ravaged by our biomass need on wood before coal came to replace them as fuel source.





Biomass: Pros and cons

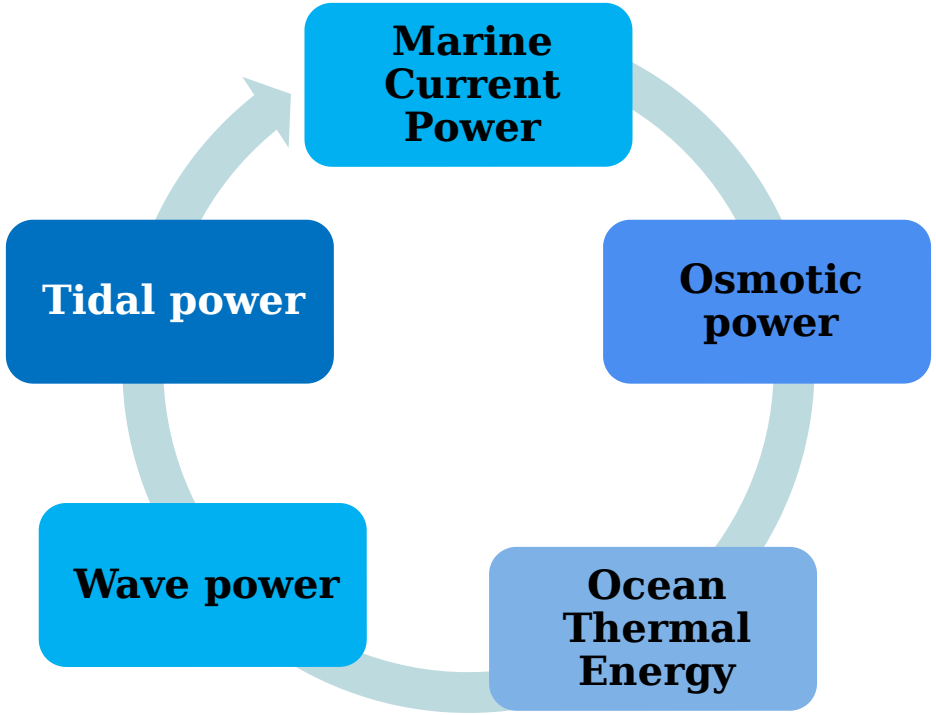
Advantages

- **Renewability and domestic availability in many countries**
- Biomass is a **carbon-neutral** energy source.
- Also, biomass may work as carbon sink to sequester carbon emissions.
- Biomass can be used in a wide selection of processes, technologies.
- Biomass can also be mixed with other feedstock, such as coal for energy purposes.

Disadvantages

- If not properly used, it **could be very polluting in domestic use** (developing and poor countries).
- **Land availability competition with harvesting plants for food**.
- Intensive cultivation of biomass may **stress water resources, deplete soil nutrients**, and displace open space, withdrawing land.
- **Energy density is low when compared with other fuels**

Ocean Energy



- We refer to the **renewable energies carried by the waves, thermal differences, tides and salinity.**
- Oceans are places with large potential energies which have rarely been used.
- Many potential locations are close to populations. Even though, large kinetic energy is also observed in far away locations.
- **All these energies are in experimental stage**, or very limited in use. There is **a long way to commercialization.**
- There is the **potential to develop 20,000–80,000 terawatt-hours per year (TWh/y) of electricity**

Global potential

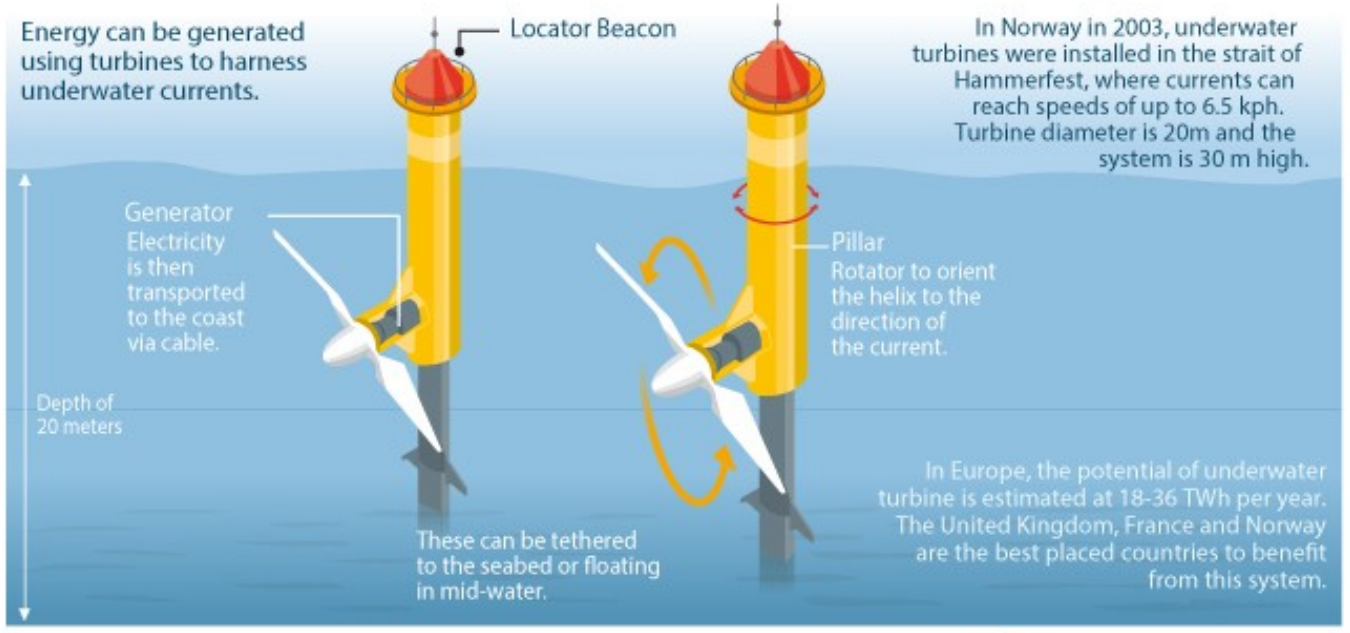
Form	Annual generation
Tidal energy	>300 TWh
Marine current power	>800 TWh
Osmotic power Salinity gradient	2,000 TWh
Ocean thermal energy Thermal gradient	10,000 TWh
Wave energy	8,000–80,000 TWh
Source: IEA-OES, Annual Report 2007[3]	

Ocean Energy

Marine Current Power

- The **oceans are places with strong marine currents circulating around continents like giant submarine rivers.**
- They are generated from a combination of temperature, wind, salinity, bathymetry, and the rotation of the Earth.
- **Marine currents are stable, with small variations in speed, location and no variation in direction.**
- Potential global power: about 5,000 GW, with **power densities of up to 15 kW/m2**.
- Devices for this energy are similar to water wheels, **open flow axial turbines located to harness the kinetic current energy**

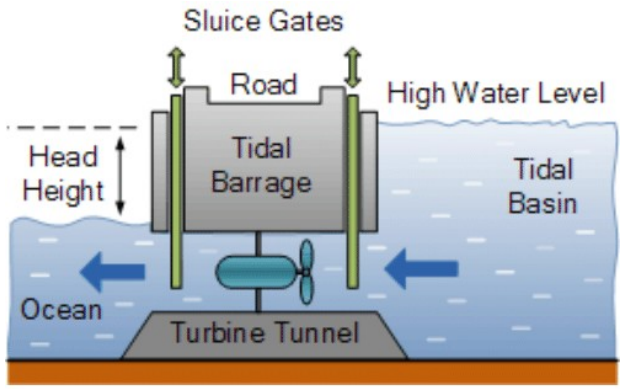
Underwater turbines



Ocean Energy

4 main Tidal technologies

- Tidal stream generator
- Tidal barrage
- Dynamic tidal power
- Tidal lagoon



Tidal Energy and how tidal energy creates electricity

Tidal power

- **Tidal power converts the energy obtained from tides into electricity.**
- **Tides sweep up and down along the coastlines** due to gravitational pull of the Moon and the Sun.
- Tidal power technologies have usually suffered of **high costs and few availability of locations**.
- Greater tidal variation and higher tidal current velocities can dramatically increase the potential of a site for tidal electricity generation.
- The picture shows the tidal barrage installation in Rance River, France.

Policy and Market Drivers

Importance of Policy Support

Critical for achieving global renewable energy targets

Highlighted by the International Energy Agency (IEA)

Goal of Tripling Renewable Power Capacity by 2030

Requires enhanced policy implementation

Challenges to Overcome

Policy uncertainties

Insufficient grid investments

Administrative barriers

Financing issues in developing economies

REGIONAL DEVELOPMENTS

- China's Leadership in Renewable Capacity
  - Economic attractiveness of onshore wind
  - Significant investments in solar PV
- Growth in the US, EU, India, and Brazil
  - Supported by favorable policies
  - Increasing economic viability
- Global Efforts for Renewable Energy Expansion
  - Crucial for increasing global renewable capacity

Hydrogen Energy

sible Contributions of Hydrogen Energy

- **Reduction of GHG by improved electrochemical** (photo electro chemical) **production of hydrogen**.
- Reduction of automotive emissions on roads
- Coupling of hydrogen production by biomass and CO2 sequestration at production plant to reduce GHG emission
- Distributed energy system

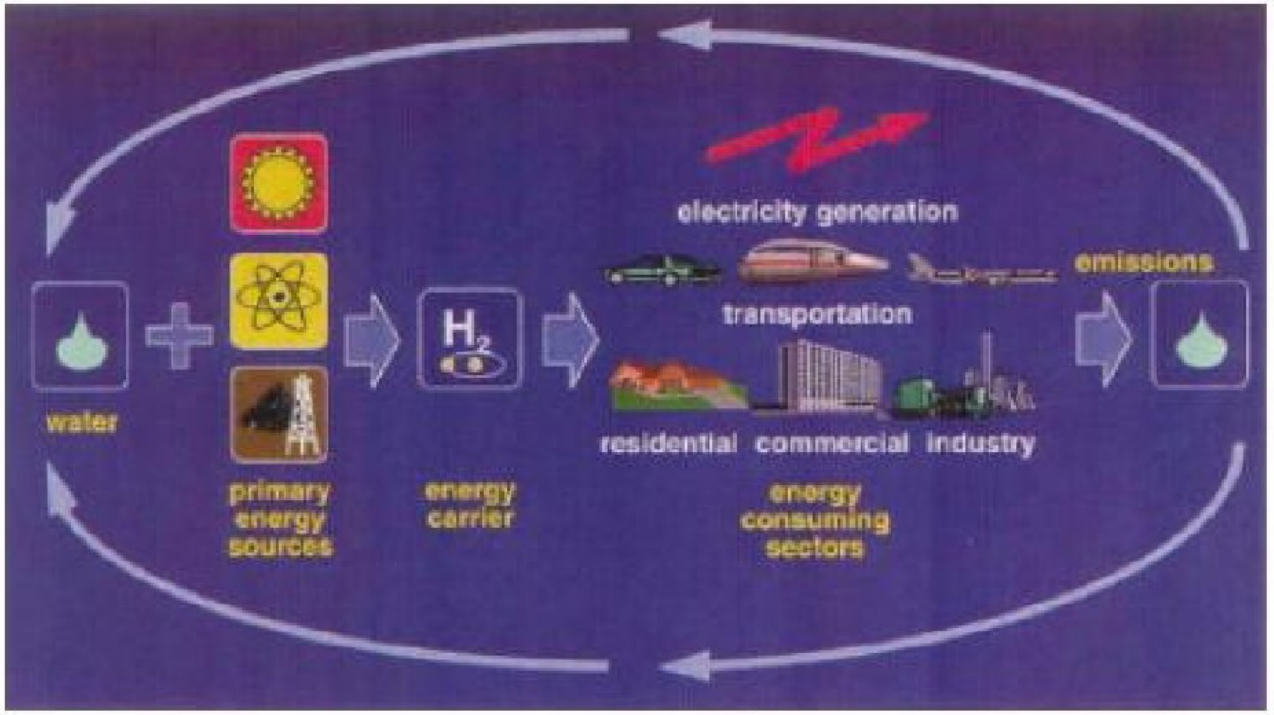
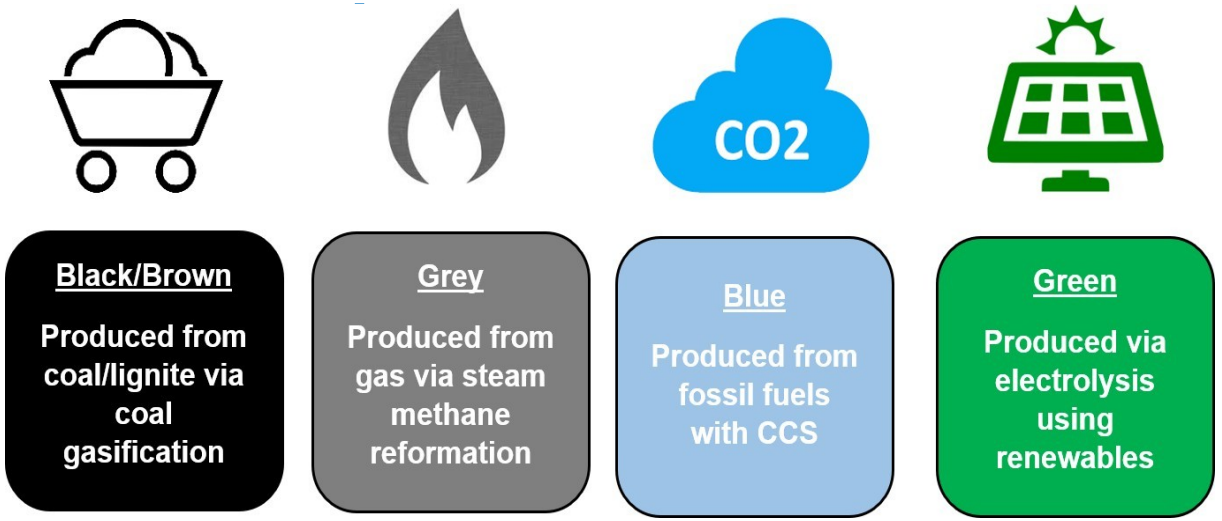


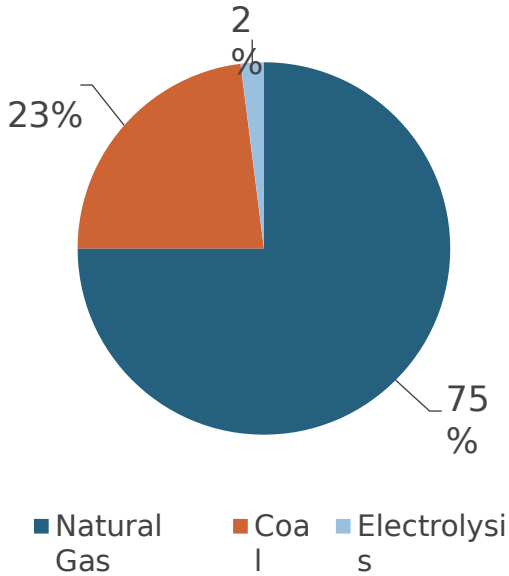
Figure 1. Hydrogen energy system [Source: International Association of Hydrogen Energy, USA].

Carbon Neutral Targets Are Driving the Case for Blue and Green Hydrogen

Different Colors of

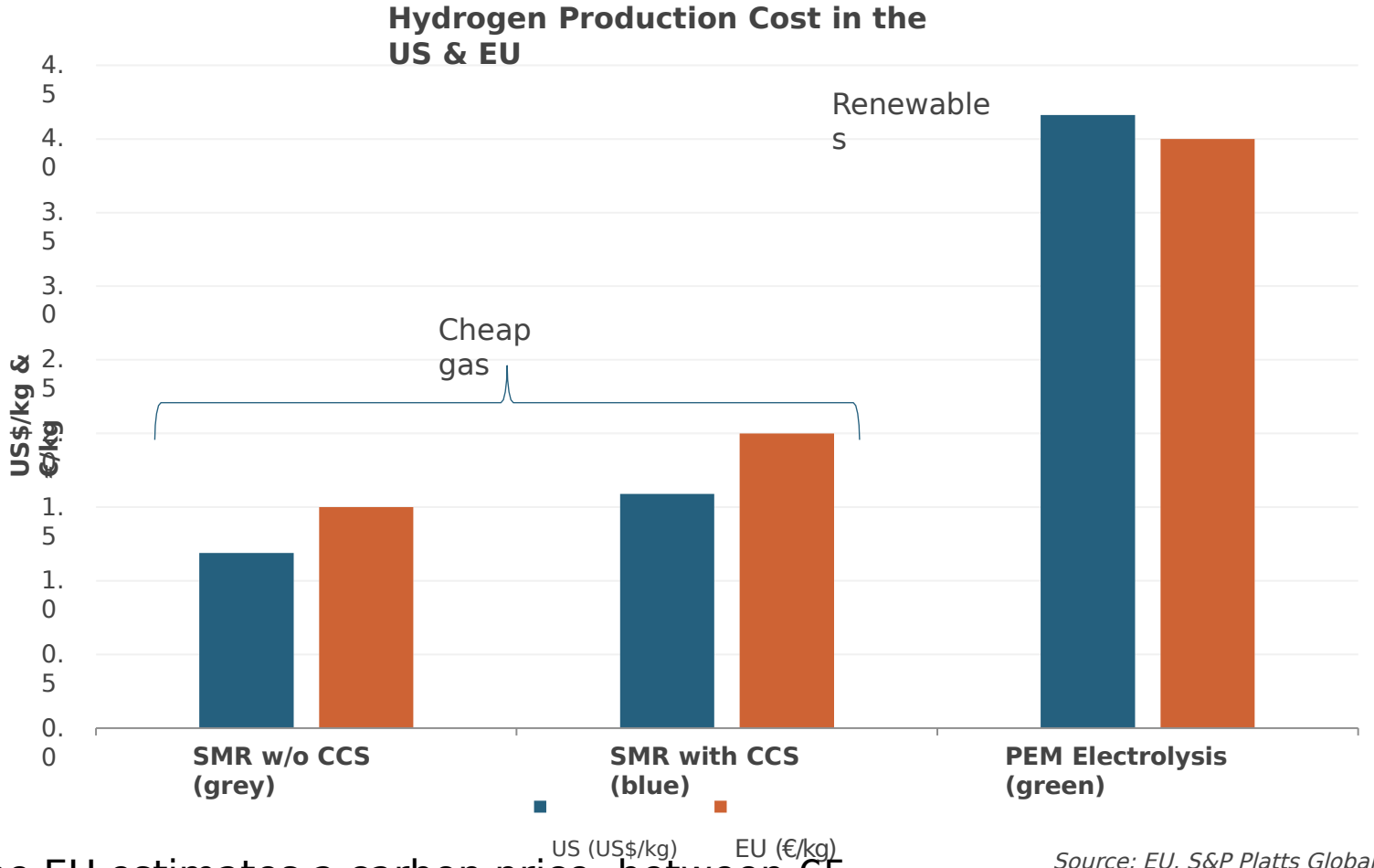


Production of Hydrogen



- **Green hydrogen is viewed as the ideal solution due to its zero-carbon footprint**, but it is currently **much more expensive than blue hydrogen**. The cost of green hydrogen is expected to be competitive with blue hydrogen by around 2030.
- **Blue hydrogen will be part of solution, but environmentalists are skeptical**, raising several concerns: 1) CCS is not 100% effective (but is close), 2) risk of CO2 leakage and 3) issue of methane emissions.
- **Blue hydrogen will help to reduce carbon emissions and build hydrogen demand during the lengthy transitionary phase.**

Cost – Feedstock Disadvantage for Green Hydrogen



Source: EU, S&P Platts Global, FGE

SMR = Steam-Methane Reforming CCS = Carbon Capture and Storage PEM = Polymer electrolyte membrane

- the EU estimates a carbon price between €55-90/tonne of CO_2 is needed to make blue hydrogen competitive with grey hydrogen today.

- The traditional way of producing hydrogen, even with CCS (blue hydrogen), is still much cheaper than green hydrogen. **The neglect of blue hydrogen and the focus on expensive green hydrogen in the EU strategy poses a challenge.**
- A substantial reduction in the electricity price is needed to make green hydrogen competitive with blue hydrogen.
- Alternatively, a significant CO_2 price

Hydrogen Is Highly Versatile, Yet Challenges Remain

Power

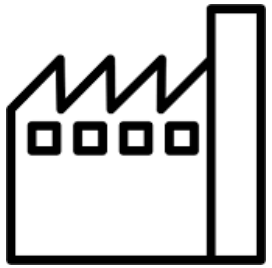
As a fuel in gas turbines/fuel cells
Hydrogen well suited for long-term storage

More economical to use renewables for power generation than to produce hydrogen

R&C

As a fuel in boilers/furnaces or fuel cells for co- generation

Significant conversion costs required to burn pure hydrogen



Industrial

Can be used as a feedstock, a reactant to remove impurities or as a fuel to generate heat
Already used on a commercial scale in oil refining and chemical production

Transport

In the maritime sector, hydrogen may be best LT solution
LNG bunkers is more developed and carbon-neutral LNG could also take off
In the land transport sector, BEVs are way ahead of FCEVs in terms of interest, scale and technology

Market Growth and Production Technologies

Significant Growth in Hydrogen Market

Green hydrogen sector projected to expand at a CAGR of over 31% from 2024 to 2032

Driven by the need for decarbonization and cleaner fuel alternatives

Green Hydrogen Production

Expected to reach 150 GW by 2030

Key factor in the shift towards sustainable energy solutions

Challenges and Opportunities

- Challenges in the Green Hydrogen Sector
  - High production costs
  - Need for substantial investments in infrastructure
- Opportunities in the Green Hydrogen Sector
  - Advancements in electrolyzer technologies
  - Reduction in costs and improvement in efficiency
  - Investment and innovation potential
  - Supportive government policies and financial incentives

GLOBAL INVESTMENTS AND PROJECTS

Surge in Global Investments

- Hydrogen industry investments reached $570 billion in 2023
- 31% increase from the previous year

Funding for Giga-Scale Projects

- Significant funding for low-carbon hydrogen projects

Infrastructure Investment Gap

- Critical for sector's growth
- Requires further policy support
- Increased market demand needed

Role of Policies in Hydrogen Economy

Policies shape the development and growth of the hydrogen sector

U.S. Department of Energy's National Strategy

Comprehensive strategy for clean hydrogen

Targets for reducing greenhouse gas emissions in hydrogen production

Impact of Policy Framework

Expected to drive investments in hydrogen sector

Encourages technological advancements

Grey Hydrogen Dominance

Cost-effective production

Extensive existing infrastructure

Prevalent in regions with abundant natural gas

Transition to Blue Hydrogen

Focus on integrating carbon capture and storage (CCS) technologies

Aim to reduce emissions from grey hydrogen production

Fuel Cells

- Fuel cells can be used in various energy systems, ranging from small devices like mobile phone batteries to vehicle applications and power plants for electricity production.
  - Higher energy conversion efficiencies
  - Less environmental emissions

					SOFC

Market Growth Projections and Adoptions

Significant Market Growth Expected

Fuel cell market projected to expand rapidly from 2024 onwards

Market Size Projections

Global market size expected to be around $12.75 billion in 2024

Forecasted to reach approximately $105.01 billion by 2032

Compound Annual Growth Rate (CAGR)

Robust CAGR of about 30.15% over the next decade

Increasing Adoption of Fuel Cells

Fuel cells are being used in various applications

Transport segment expected to see highest growth

Rising Demand for Clean Transportation

Fuel cell electric vehicles (FCEVs) are gaining popularity

Governmental investments in hydrogen infrastructure

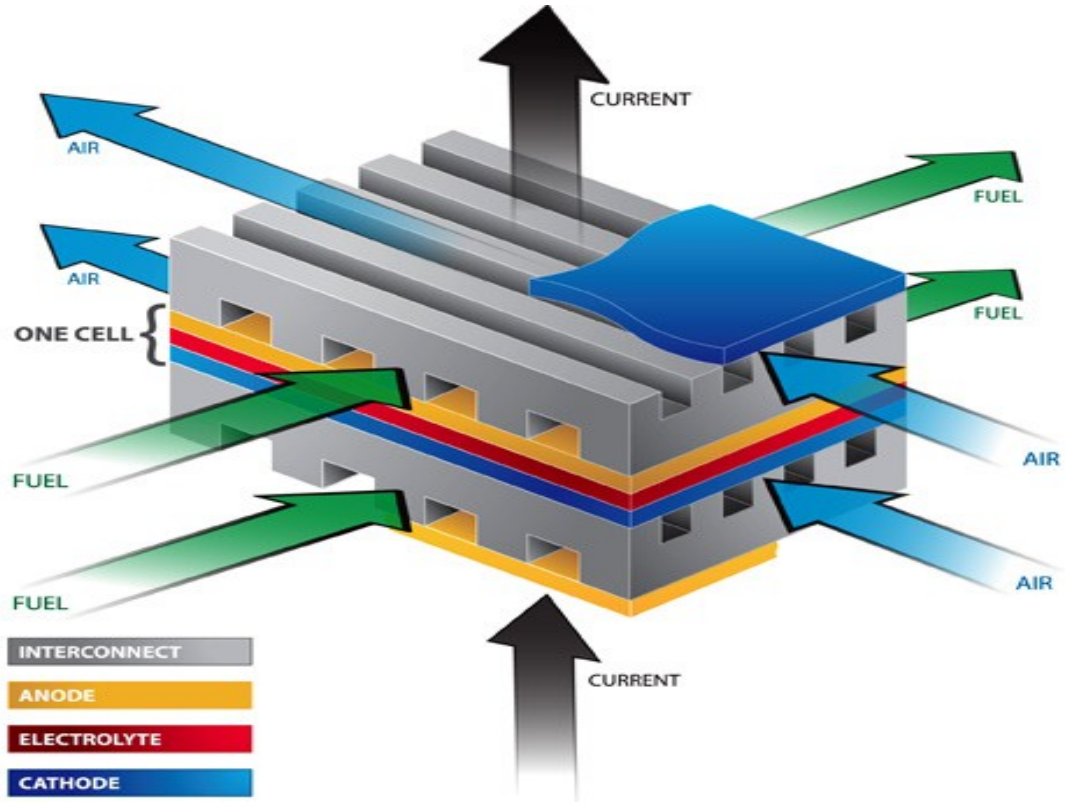
Emissions reduction policies support FCEV adoption

Key Countries Driving Growth

- South Korea
- Japan

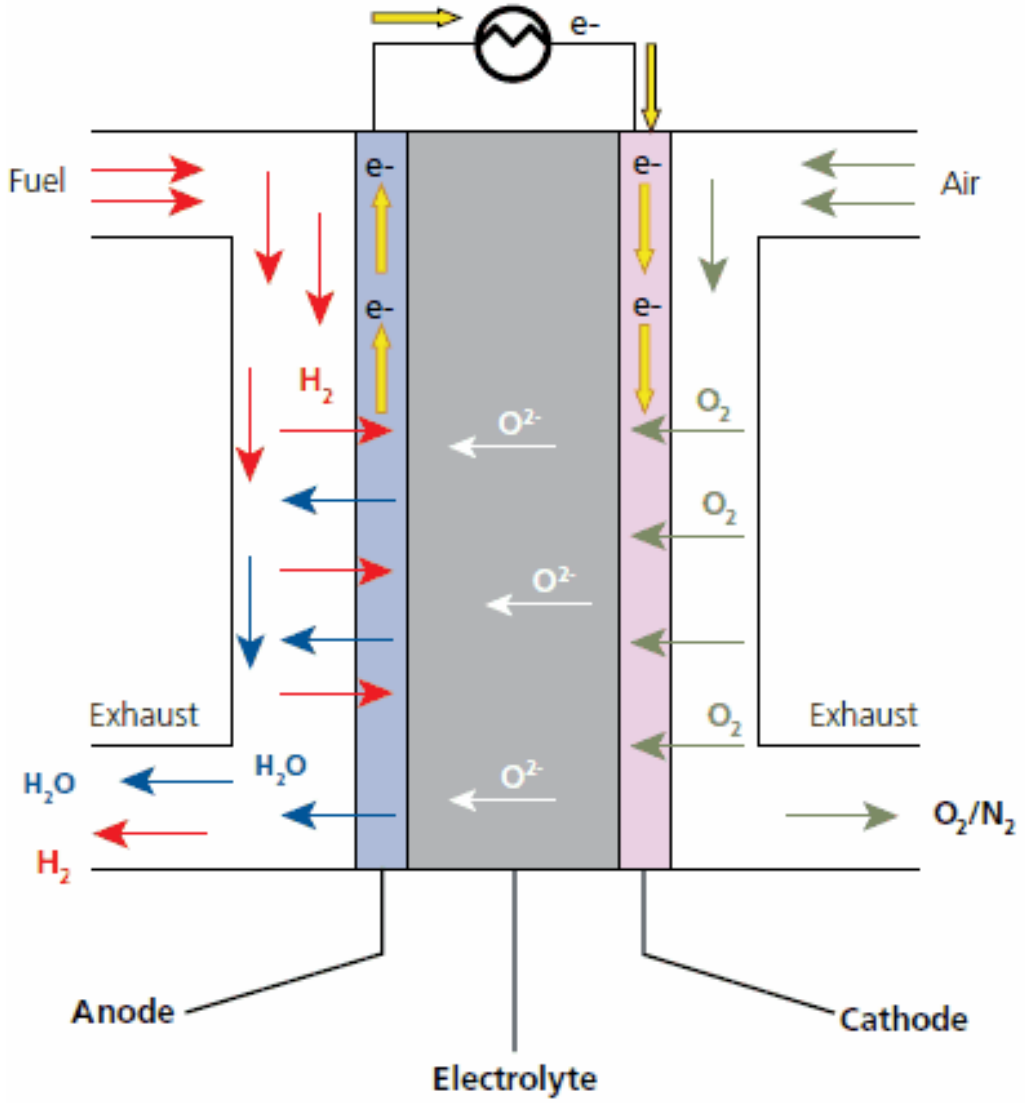
Solid Oxide Fuel Cell (SOFC)

- Energy conversion device that generates electricity and heat by electrochemical reactions.
- Ability to convert chemical energy directly into electrical energy without a need for combustion
- Hydrocarbons used as a fuel for SOFCs especially the natural gas
- More efficient and cleaner transformation of natural gas into electricity
- Can be used for the electricity production in large-scale stationary installations.
- High efficiency, low emissions, low-cost electricity and scaling flexibility
- Higher conversion efficiencies than most conventional thermo-mechanical methods
- Lower carbon dioxide emissions compared to fossil-based energy generation technologies.



SOFC Features

- An energy conversion device that generates electricity and heat by electrochemical reactions combining a gaseous fuel and an oxidizing gas via an ion-conducting electrolyte.
- Ability to convert chemical energy directly into

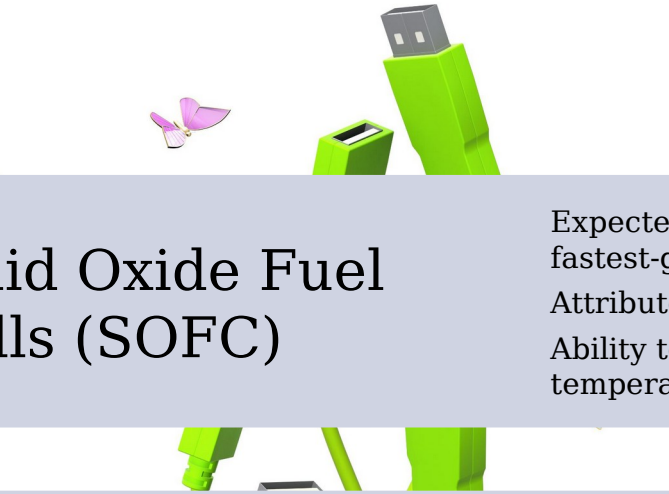


Applications of SOFCs

Stationary Power Generation	Efficient electricity generation for residential, commercial, and industrial buildings
Combined Heat and Power (CHP) Systems	Ideal for applications where both electricity and heat are used due to high operating temperatures
Auxiliary Power Units (APUs)	Used in heavy-duty vehicles, ships, and aircraft to provide electricity without running the main engine
Portable Power	Adaptable for portable power applications due to high energy efficiency, though less common

- Supportive Countries
  - Japan and South Korea lead in SOFC deployment
  - Integrated into national energy strategies
  - Focus on hydrogen economies and carbon reduction
  - U.S. and European nations, notably Germany, support through funding and research
- Non-Supportive Countries
  - Lack specific policies or incentives for fuel cell technology
  - Heavily dependent on fossil fuels
  - Absence of significant renewable energy transition policies

Technological Advancements



Solid Oxide Fuel Cells (SOFC)

- Expected to be one of the fastest-growing segments
- Attributed to their efficiency
- Ability to operate at high temperatures

Advantages of High Temperature Operation

- Reduces the need for costly catalysts
- Eliminates the necessity for platinum

- Major Companies in the Market
  - Ballard Power Systems
  - Bloom Energy
  - FuelCell Energy
- Strategic Initiatives
  - New product development
  - Partnerships to enhance market position
- Market Growth Drivers
  - Increasing environmental concerns
  - Advancements in technology
  - Supportive government policies

Impact of Policy on SOFC Development

Government Policies and SOFC Development

- Positive policies like subsidies and grants accelerate SOFC adoption
- Incentives for clean energy technologies boost SOFC growth

Negative Impact of Absence or Opposing Policies

- Lack of supportive policies hinders SOFC development
- Policies favoring other energy types can slow SOFC growth

U.S. Department of Energy (DOE) Initiatives

- DOE's Fuel Cell Technologies Office (FCTO) supports SOFC research
- Funding and technical assistance provided by FCTO

European Support through Horizon Europe

- Horizon Europe program backs research in energy technologies
- Includes support for SOFC innovation

Future of SOFC Among Other Energy Generators

High Efficiency and Versatility

SOFCs are highly efficient in energy conversion

Can utilize various fuels such as hydrogen, natural gas, and biogas

Role in Decarbonization

Integral to energy systems with renewable sources

Supports global decarbonization efforts

Challenges

High upfront costs

Requirement for high operating temperatures

Ongoing Development

Advancements in materials science

Future Competitiveness

Future Outlook

Energy Transition Trends

Global shift towards renewable energy

Decarbonization redefining market dynamics

New opportunities and challenges

Investment Opportunities

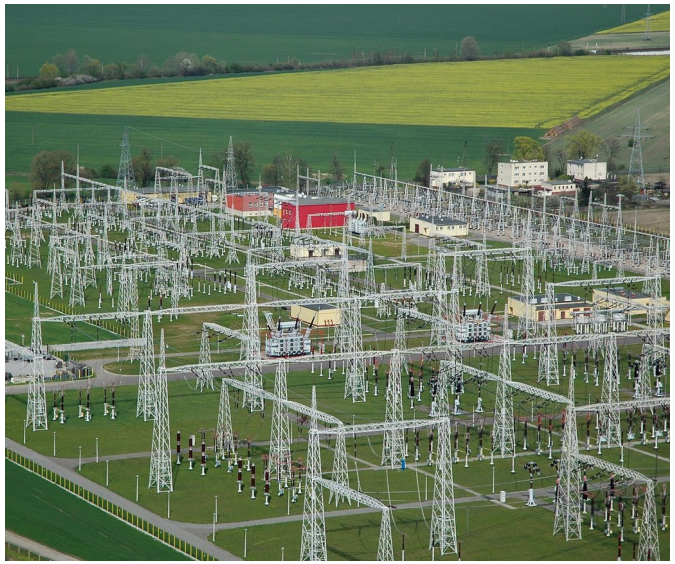
Invest in renewable energy technologies

Develop hydrogen fuel infrastructure

Focus on SOFC development

Energy Trends:
Take away

Energy Sector Overview



Global Energy Consumption

The global demand for energy continues to grow steadily, driven by population growth, urbanization, and economic development in emerging economies.

Energy Production and Trade

IRENA and IEA data show that renewable energy sources are growing rapidly, while demand for fossil fuels is expected to decline in the coming years.

Key Trends and Challenges

The energy sector is facing several key trends and challenges, including climate change, geopolitical tensions, and the need to transition to a low-carbon economy.

Energy Sector Challenges and Opportunities

The energy sector is facing significant challenges and opportunities in 2024, with demand for energy continuing to grow and renewable energy becoming an increasingly important part of the global energy mix.

Renewable Energy

Solar and Wind Power

Solar and wind power are the dominant sources of renewable energy investment, accounting for the majority of investments in 2020.

Investment Leaders

China, the US, and Europe are the leading investors in renewable energy, accounting for a significant portion of the total investment in 2020.

Renewable Energy Sources

With the increasing demand for energy, there is a need for renewable energy sources to help meet the energy demand. Renewable sources such as wind, solar, hydro, and geothermal energy are being increasingly used to produce energy.

Global Renewables Capacity

Renewable energy capacity around the world is increasing rapidly, driven by low costs and government support. Wind and solar power are the fastest-growing renewable energy sources, with total capacity exceeding 1,500 GW worldwide.

Renewable Energy Investment

Renewable energy investment has grown exponentially over the past years, reaching a record $332 billion in 2020. Most of this investment is focused on wind and solar power, followed by hydropower and bioenergy.

Renewable Energy Technology

Renewable energy technology is advancing rapidly, with new innovations in wind and solar power, energy storage, and smart grid systems. These technologies are making renewable energy more reliable and cost-effective than ever before.

Thanks

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